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ALLAN W. CUDDEBACK, President 1926–1927

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AMERICAN WATER WORKS ASSOCIATION

VOL. 16 OCTOBER, 1926 No. 4

UNIVERSAL METERING OF WATER SUPPLIES[1]

By John Ericson[2]

About three years ago I instructed Col. Henry A. Allen of the City Engineer's staff to proceed with the collection of all available data on the subject of metering water supplies, and to present the same in tabular and statistical form with such explanations, comments and conclusions as would be advisable, especially as it would affect the City of Chicago. The purpose of the study was to bring out as clearly and accurately as practicable, both by a policy of continuing under then prevailing conditions, as well as by adopting a practical policy of metering of the water supply, the effect on:

1. Capital Investments
2. Operating Costs
3. Revenues
4. Purification
5. Health and such other related subjects as may be pertinent to the question

I suggested also that the investigation cover the past records of the Chicago System as far as necessary and the projected results for a period of about thirty years in the future.

[1] Presented before the Buffalo Convention, June 8, 1926.
[2] City Engineer, Chicago, Ill.

In presenting his report Col. Allen prefaced the same with some pertinent remarks, part of which were as follows:

Equality is generally linked with rights. The citizen most invariably assumes that what he claims as a right he should have and that the Government should enforce his possession thereof. Unfortunately, rarely does the citizen look at the necessary corollary to the claim of a right, that the other citizens have equal claims to their rights. The citizen must, therefore, grant those others their rights, and must assist in enforcing the rights of others even against himself. This, otherwise stated, means that all citizens have equal rights. Often, just at this point, selfishness, avarice, negligence and similar characteristics begin to interfere with the good order of things; many citizens are unable to restrain themselves when dealing with the plain rights of others, and still other citizens are unable to recognize in the state, the whole, of which they are a part. What injures the state injures the individual. Many who will not violate any principles of good government as respects individuals are totally conscienceless as respects the state, and look upon the state as something to be bled or drawn upon for personal gain. This view is fostered by general public indifference; otherwise expressed, "what is everybody's business is nobody's business."

TABLE 1

Population supplied, Chicago	3,023,279
Population supplied, Suburbs	218,045
Total population supplied	3,241,324
Number of services metered	43,000
Number of services unmetered	329,366
Total net pumpage	323,881,000,000 gallons
Delivered through meters	100,196,219,000 gallons
Unmetered supply	223,684,781,000 gallons
Revenue from metered water	$6,161,214.07
Revenue from unmetered water	$3,833,552.53
Free water, estimated	$1,200,000.00

Applying the above to the concrete, every citizen having equal duties with all other citizens should perform such duties. He should render a just return for all his rights. Failing to do this, he is encroaching on the rights of others and denying his own fundamental claim.

The rate for services rendered by the State should be just and equitable. As the state does not operate for profit, the rates for services should be based on the cost of such services and so paid for. Then will both rights and duties be conserved.

At all times, in attempting to enforce duties, specious arguments are introduced to avoid their performance, and, therefore, in effect, denying others their rights.

Square dealing should be the prime consideration, not only between individuals, but between municipalities and governments and their individual

citizens. Favoritism and paternalism cannot but result in dissatisfaction and eventually in anarchy.

Discriminatory or class legislative rates are basically illegal. It would seem possible that a large user of water purchased on measurement or metered basis could have issued a mandamus order to compel the city to charge for water to others under similar conditions at the same just rate. This brings up the question—can discriminatory or class legislative rates be justified or held by due process of law? A water consumer is entitled to receive that for which he pays, and no water consumer, at the expense of others, is entitled to receive more than he pays for.

As a concrete example of how the principles emphasized in the foregoing remarks are actually applied in the City of Chicago, as far as its water supply system is concerned, I present the data in table 1 showing the results of its operation in 1925.

An analysis of these figures will show that the metered consumers in that year were paying 62 per cent of the total revenues for 30 per cent of the water pumped, while the unmetered consumers paid 38 per cent for 70 per cent of the pumpage. Deducting the amount of free water, estimated at 17,640,000,000 gallons, the metered consumer paid at an average rate of 6.15 cents and the unmetered consumer at a rate of 1.87 cents per 1000 gallons of water received. When considering that the metered consumers were those using large quantities of water, this unfair distribution of charges becomes even more marked.

As far as Chicago is concerned, to call the above quoted principle to her attention seemed, therefore, to be quite justifiable.

One of the arguments against metering public water supplies that one frequently hears is that water like air is a God made commodity and should be as free. This argument appeals particularly to people in a city located on a Great Lake, like Chicago. If water were as universally distributed as air is, there might be some logic in this argument, but, while the average citizen when turning on the faucet in his home seldom stops to think of what is required to give him this convenience, we water works men know what time and effort and money are needed and expended to construct conduits, pumping stations, pipe lines, purification plants and what not, that are essential factors in nearly every water works system.

While air in its natural state and pressure, permeating as it does every space and crevice on the earth, without any effort or expense on the part of man, is truly free, those that require it at pressures greater than nature provides find that even air is not free, but that it must be paid for on an equitable basis.

Electricity for the purpose of this argument may be considered even more universally distributed than water and even than air, but when harnessed and furnished for the use of mankind it is distributed and paid for on an equitable and fair basis.

The method that has been and still is in vogue in so many cities of charging for water on the so-called frontage basis has led to the unfair distribution of charges for, and a great waste of, this commodity that we find in so many places.

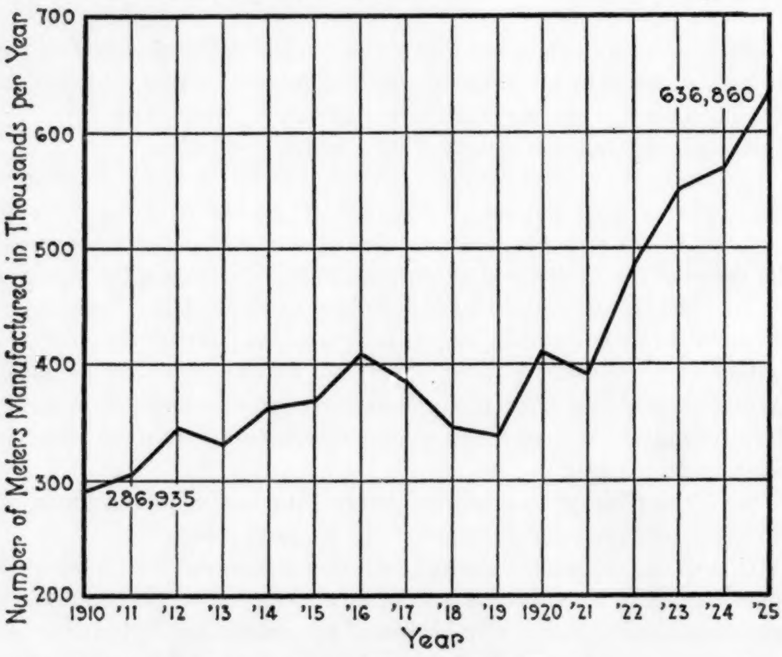

Fig. 1. Meters Manufactured 1910 to 1925 (Five Manufacturers)

That there has been an awakening to the injustice and injury caused by this method is evidenced by statistics and reports that have become available from time to time (see figure 1). Some communities have acted with promptness in this matter as soon as the economical part of the question has been pointed out and understood; others have adopted measured service of their water supplies out of sheer necessity and as the final solution of the problem of furnishing the citizens with the necessary supply of water. Other cities have persistently refused even to listen to any arguments or to facts tending to show the unfairness of the frontage method and to any evi-

TABLE 2

Universal water metering. Reduction in consumption due to metering in cities that have adopted a universal metering program

CITY	UNIVERSAL METERING ADOPTED DATE	PER CENT OF SERVICES METERED				PER CAPITA CONSUMPTION				POPULATION TIME OF ADOPTION	ESTIMATED POPULATION JULY 1, 1925	PER CENT IN-CREASE	MAX. RATE PER 1000 GALS.
		5-years previous	Time of adoption	5-years after	1925	5-years previous	Time of adoption	5-years after	1925				
													cents
Detroit	1913	10.0	23.6	97.4	99.07	162.0	163.0	144.0	130.0	624,139	1,257,634	101.0	8.7
Cleveland	1901	4.9	68.0	100.0	100.0	168.9	130.7	96.1	127.4	399,658	912,502	128.0	8.0
Los Angeles	1905	0.0	19.1	55.4	99.0	300.0	175.0	141.0	119.0	210,838	705,411	234.0	9.7
Milwaukee	1899	61.0	83.0	95.0	99.0	101.0	83.0	86.0	128.0	277,231	492,087	77.0	9.3
Newark	1915	49.0	60.6	92.2	95.3	107.0	110.0	108.2	100.2	380,996	445,606	14.0	19.2
Minneapolis	1905	25.1	45.7	79.6	100.0	92.7	66.5	73.8	107.8	252,063	417,280	65.0	8.0
Cincinnati	1915	32.8	64.9	98.2	98.6	127.8	125.9	123.4	116.1	382,419	407,835	6.0	16.0
Kansas City, Mo	1905	29.0	38.0	44.4	82.5	60.7	93.8	98.0	125.7	206,066	359,650	74.0	22.7
Rochester	1905	28.6	41.0	97.0	99.0	76.2	78.9	80.8	93.9	190,378	325,211	71.0	16.0
Columbus	1905	32.0	76.2	91.31	99.1	150.0	59.6	75.6	92.8	153,530	266,709	74.0	16.0
Oakland	1910	43.6	57.2	100.0	100.0	90.9	85.6	54.3	64.1	150,174	246,893	64.0	27.9
St Paul	1912	51.1	84.8	97.3	99.5	60.7	60.9	81.2	71.5	218,734	243,946	12.0	12.0
Akron	1912	25.0	45.0	100.0	100.0	106.3	117.2	93.2	87.0	96,941	278,119	187.0	21.4
Average of 13 cities	Since 1901	30.1	54.39	87.5	97.8	123.4	103.8	96.5	104.8	3,543,167	6,358,883	79.0	15.0

dence tending to show the great economy and advisability of a measured water supply.

There has been a great deal written and published on the subject of metering of water supplies, and to present anything new on the subject in general to a body of men such as are gathered here at this Convention is not an easy task, nor do I presume that I can do so. I have, however, gathered some additional up-to-date information, which does not bring out any startling new facts, but which may be of interest in some respects and a confirmation of other statistics formerly presented.

Table 2 explains itself. It will be noted that even after a system has become 100 per cent metered there is a gradual upward trend in the average per capita consumption. This, of course, can be no argument against meters. It is generally due to one or more of the following causes:

1. An increasingly higher standard of living.
2. Increased pressures in the system.
3. Reduced rates by reason of more economical operation.
4. Increasing industrial activities.

It can be seen from this table that metering unfailingly tends to reduce the per capita pumpage and, consequently, the cost. Pressures are increased and a more equal distribution of charges for services rendered is made.

As an illustration of the result of the frontage system of charging for water and what metering may accomplish, the following may serve as an object lesson:

A section in the southeast part of the City of Chicago named Hegewisch was known for its great waste of water. This is a residential district consisting of small homes and two-flat buildings. The few industrial plants in the district use water at a comparatively low rate, namely, about 26 gallons per capita per day.

Irrespective of the fact that the former ordinance did not require the metering of premises such as were to be found in this district special permission was obtained and means provided for metering all premises therein for the purpose of noting the effect thereof.

It was understood between the city officials, but not communicated to the citizens, that the meters thus placed were not to govern the charges for water, but that these were to be continued to be based on frontage rates as before. These meters were placed during the latter part of 1920. Immediately after being placed these meters,

a total of about 850, were read, and about a year later a second reading was made to determine the amount of water that had passed through each meter during that time.

The great variation found to exist in the use of water in the various premises was astonishing. Thus, one two-flat building that was paying $9.28 per year under the frontage rate was found to have been using water to the amount of $145.17 under the meter rate, or at a rate of 1587 gallons per capita per day. Another similar building paid $9.76 to the city, while the meter showed that water to the value of $171.49 passed into the premises. Another paid $6.38, while the meter showed that $185.98 should be the proper charge, and so on.

On the other hand, there were many premises that had used less water than they would have been entitled to under the meter rates. Thus, one paid $11.64 per year, while only water to the value of $6.07 passed through the meter, or at a rate of 44 gallons per capita per day. Many similar cases were found. Many premises were found to have a very low consumption per capita, principally in streets where there were no sewers and no inside plumbing.

Another interesting lesson learned from this experiment was the moral effect that the placing of these meters seemed to have on the population of this district as far as the use of water was concerned. Before the placing of the meters the average domestic daily per capita consumption in this district was at a rate of about 433 gallons. Thirteen months after the meters had been placed this domestic average consumption had been reduced to about 75 gallons. As the people began to realize that the cost of water remained the same, whether they wasted it or not, the consumption gradually increased until it again has reached about 160 gallons.

This is the first district that has been placed on metered rates under the new ordinance. It is expected that the average per capita consumption will again be reduced to about 75 gallons per day. These results are graphically shown in figure 2.

The water supply question in Chicago may or may not in general differ materially from that in some other American cities, except that the per capita consumption there is unusually high, being 285 gallons per day, but, being somewhat more familiar with the situation in that city, I shall beg your indulgence for describing somewhat in detail what the water supply problem in general has been and is there, as it may be applicable to other cities.

Chicago is fortunately situated on the shore of one of our Great Lakes, so that there is always a potential, inexhaustible supply of water right at our doors. Owing to the gradual pollution of the waters in the vicinity of the city by sewage, shipping and from other sources, it has been necessary for many years to place the intakes two, three and four miles out in the Lake. This again has necessi-

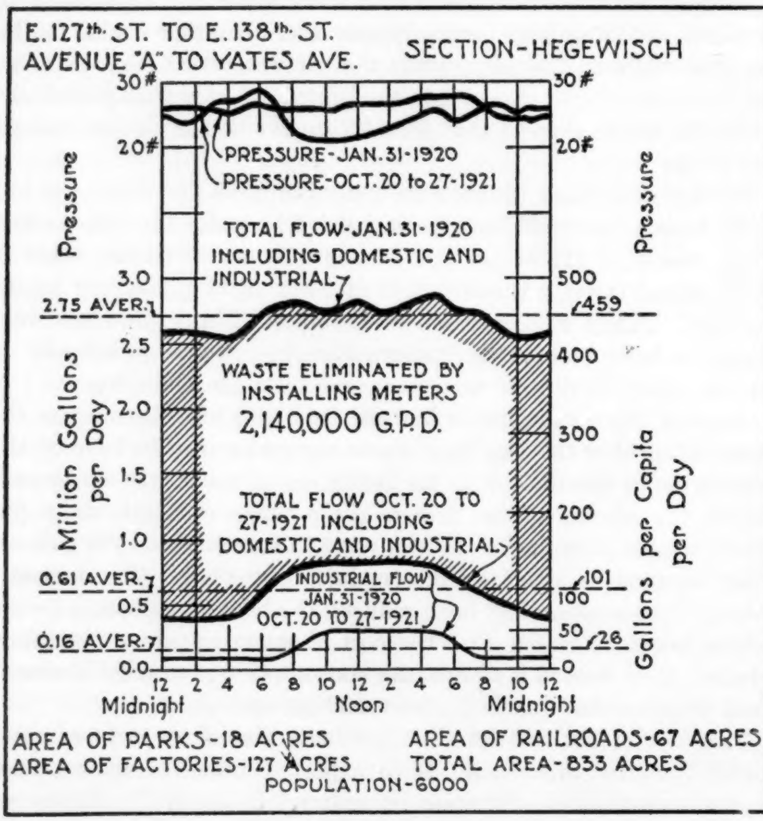

FIG. 2. EFFECT OF METERING IN ONE SECTION OF CHICAGO

tated the building of tunnels and intake cribs, which require considerable time in construction.

Owing to the rapid growth in area and population by annexations of contiguous communities, as well as by natural increase, and owing to the rapidly increasing per capita requirement in pumpage, there has been a continuous, feverish construction activity that has

tried the financial and physical resources of the city to the limit, especially as no bonds placing any burden on the community at large for water supply purposes have been sold, all extensions and additions to the system having been paid for out of revenues for water. These facts are graphically shown in figure 3.

When about the year 1900 two large new pumping stations and

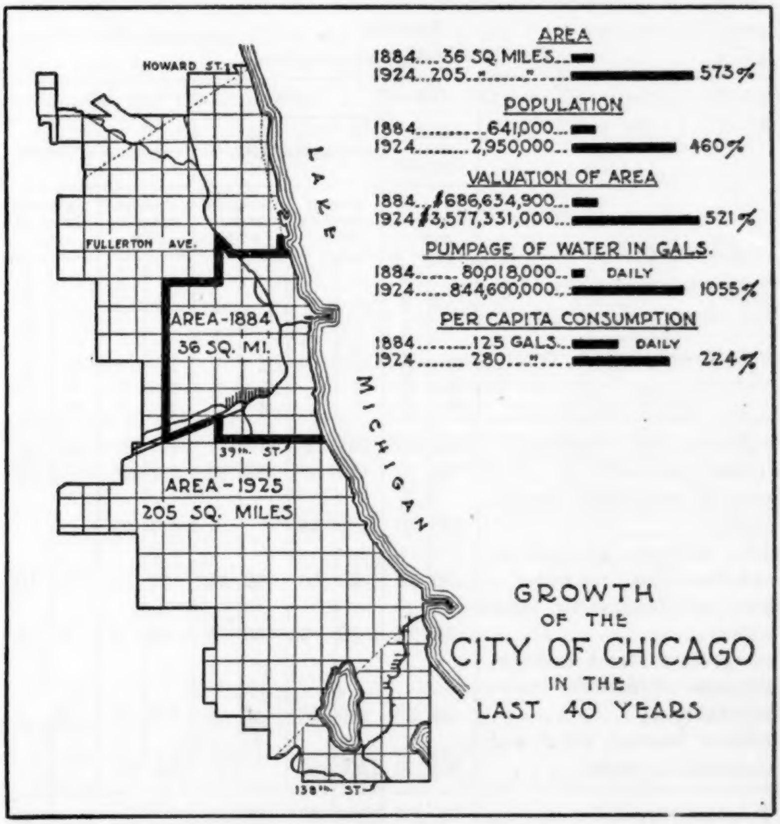

FIG. 3

some additional pumps in some of the older stations, added to the system, were placed in operation, increasing the then available capacity of 323 to 500 m.g.d., or over 50 per cent, it was expected that there would be a let-up in the construction activities for some time, and that Chicago would have an ample supply for many years to come.

Hardly more than a year had passed after this great increase in capacity before many complaints of unsatisfactory service again reached the City Engineer's office. A special investigation was then made by the City Engineer to ascertain what became of all the water pumped. It was found that less than 50 per cent served useful purposes and was really needed, and that the balance of the pumpage

TABLE 3

Estimated water consumption

DISTRIBUTION	1925		1960				1960			
	POPULATION 3,000,000		POPULATION 5,000,000				POPULATION 7,000,000			
	Present metering plan		Present metering plan		Universal metering plan		Present metering plan		Universal metering plan	
	M.G.D.	Gallons per capita	M.G.D.	Gallons per capita	M.G.D.	Gallons per capita	M.G.D.	Gallons per capita	M.G.D.	Gallons per capita
Commercial and industrial	165	55	305	61	305	61	427	61	427	61
Domestic, metered	59	20	150	30	375	75	210	30	525	75
Domestic, unmetered (legitimate)	120	40	225	45			315	45		
Public, religious, educational and charitable (free water)	30	10	50	10	50	10	70	10	70	10
Parks and boulevards (free water)	18	6	30	6	30	6	42	6	42	6
Underground street leakage, slippage of meters, unaccountable	84	28	140	28	40	8	196	28	56	8
Plumbing leakage, wilful and unavoidable waste	364	121	1300	260			1820	260		
Total average daily pumpage	840	280	2200	440	800	160	3080	440	1120	160

was lost through plumbing leaks, leaks in mains, pump slip, and through wilful and unnecessary waste.

A similar situation was found to have existed in other Lake cities, as well as elsewhere, and a satisfactory solution had been found in metering the systems.

A report setting forth the facts as found was then submitted to

the proper authorities. This report called attention to the conclusions to be drawn from the investigation; that neither the financial nor the physical resources of the city would eventually permit the policy as pursued in Chicago to continue, and that the city without delay should, therefore, adopt an ordance providing for the metering of the system in the shortest practicable time.

It is undoubtedly known to many of you what persistent and continuous efforts have been made during the past twenty-five years, since this first report was made, to bring about this much needed reform in the management of the Chicago Water Supply System.

In order to illustrate how important this matter really was and

TABLE 4

Revenue and expense 1925 to 1960

	POPULATION 5,000,000		POPULATION 7,000,000	
	Present metering plan	Universal metering plan	Present metering plan	Universal metering plan
Total revenue	$557,000,000	$452,000,000	$712,000,000	$555,000,000
Operation	$310,000,000	$193,000,000	$390,000,000	$240,000,000
Repairs and renewals	150,000,000	107,000,000	190,000,000	134,000,000
Additions and extensions	164,000,000	21,000,000	210,000,000	30,000,000
Total expenditures	$624,000,000	$321,000,000	$790,000,000	$404,000,000
Excess expenditures	$67,000,000		$78,000,000	
Surplus revenue		$131,000,000		$151,000,000

has since become to the City of Chicago, I have had prepared some diagrams and tables, which are presented herewith. They are self-explanatory and need but little comment.

Chicago's Water Supply System at the end of the year 1925 consisted of the following main items:

Intake Cribs	6
Miles of Water Tunnels	70
Pumping Stations	10, the 11th being under construction
Distribution Mains	3300 miles
Services metered	43,000
Services unmetered	329,366
New services added per year	about 8000
Nominal pumping capacity	1,100,000,000 g.d.

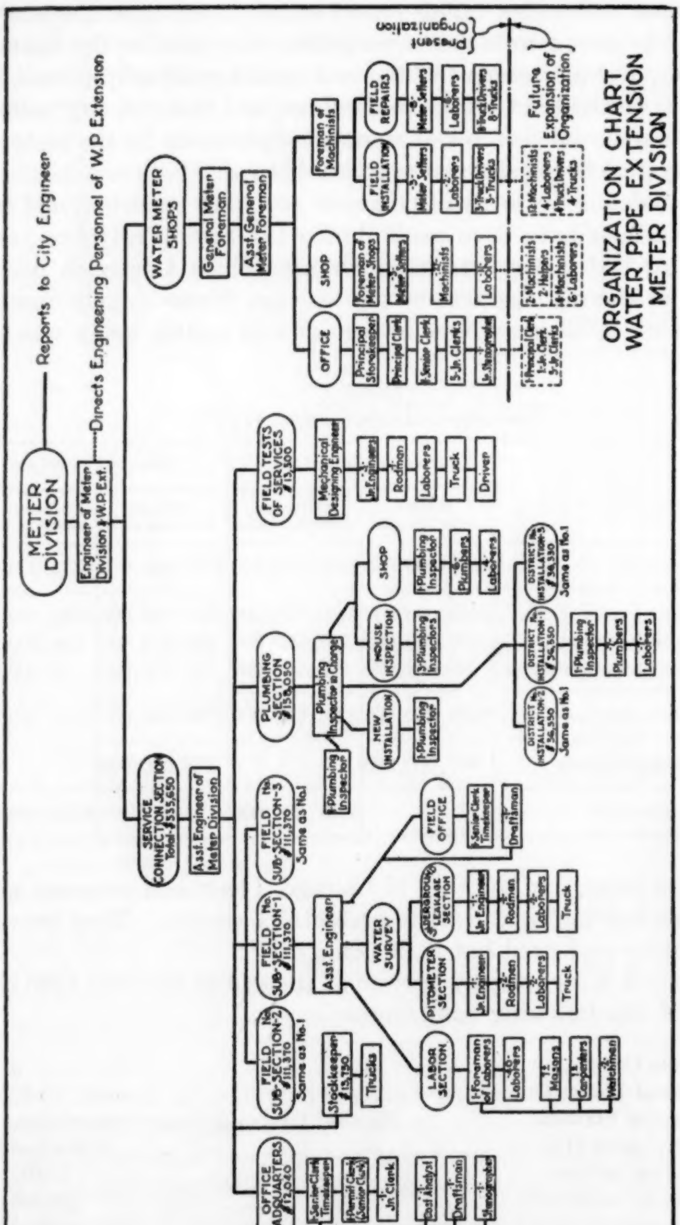
METER DIVISION
Reports to City Engineer
Engineer of Meter Division & W.P. Ext.
Directs Engineering Personnel of W.P. Extension
SERVICE CONNECTION SECTION Total-$335,650
Asst. Engineer of Meter Division
WATER METER SHOPS
General Meter Foreman
Asst. General Meter Foreman
OFFICE HEADQUARTERS $12,040
FIELD SUB-SECTION-2 No. $111,370 Same as No.1
FIELD SUB-SECTION-1 No. $111,370
FIELD SUB-SECTION-3 No. $111,370 Same as No.1
PLUMBING SECTION $158,050
FIELD TESTS OF SERVICES $13,300
Stockkeeper $13,750
Trucks
Asst. Engineer
LABOR SECTION
WATER SURVEY
FIELD OFFICE
PITOMETER SECTION
UNDERGROUND LEAKAGE SECTION
Plumbing Inspector in Charge
1-Plumbing Inspector
NEW INSTALLATION
HOUSE INSPECTION
SHOP
Mechanical Designing Engineer
Jr. Engineers
Rodmen
Laborers
Truck
Driver
Draftsman
OFFICE
SHOP
FIELD INSTALLATION
FIELD REPAIRS
Foreman of Machinists
Principal Storekeeper
Foreman of Meter Shops
Machinists
Laborers
Present Organization
Future Expansion of Organization
ORGANIZATION CHART
WATER PIPE EXTENSION
METER DIVISION

FIG. 4

It will be seen by examining tables 3 and 4 that unless a universal metering policy or some other practical method of eliminating leakage and waste, be adopted, if the population should increase to 7,000,000 in 1960, which, according to authorities such as Professor Goode of the University of Chicago, Professor Bailey of the Northwestern University, and the Chicago Plan Commission, is a very conservative estimate, this present great system would have quadrupled in thirty-five years, allowing maximum consumption to be 150 per cent of the average.

Due principally to the position unexpectedly taken by the United States Government in making it a provision, in granting a permit to the city for the withdrawal of the needed quantity of water from Lake Michigan for sewage dilution purposes, that the city meter its water supply in a period of ten years, the City Council on September 1, 1925, passed a universal meter ordinance, which ordinance is now in effect.

Thus the first victory in this long drawn out battle has been won.

The next step in this municipal drama is not any less formidable.

There are about 330,000 unmetered services to be metered in ten years. With 6000 or more new services added each year, a program, whereby some 40,000 meters must be installed yearly during the next decade, confronts us.

Considerable thought was given to an organization that would be able to accomplish this task. Figure 4 shows the organization recommended by the City Engineer. This aimed at a concentration of authority and responsibility and to facilitate the work we had in hand, so that there would be the least possible lost motion.

The Water Pipe Extension Division, one important branch of the Bureau of Engineering, which has supervision over the construction, maintenance and repairs of the distribution system, has always had as its head a Superintendent who was not required to be and is not an Engineer. This is an inheritance from the old political system, although the position is now under civil service, but not classified under the Engineering Service. Some years ago practically every man, including the superintendent, foremen and caulkers, but excepting the engineering and clerical sections of this Division, became a member of the Plumbers' Union. Since that time the Union has made it a rule that plumbers and plumbing inspectors must not take orders from anyone not a member of this organization.

In order to avoid strikes and other difficulties and as previous meter connection work had been a function of the Water Pipe Extension Division, the meter installation program, with the exception of setting meters, was therefore left to be carried on practically as before the passing of the universal meter ordinance.

The meter testing, repairing and setting has been done under a Meter Shop Superintendent, who reports directly to the City Engineer. The men employed in this Division are members of

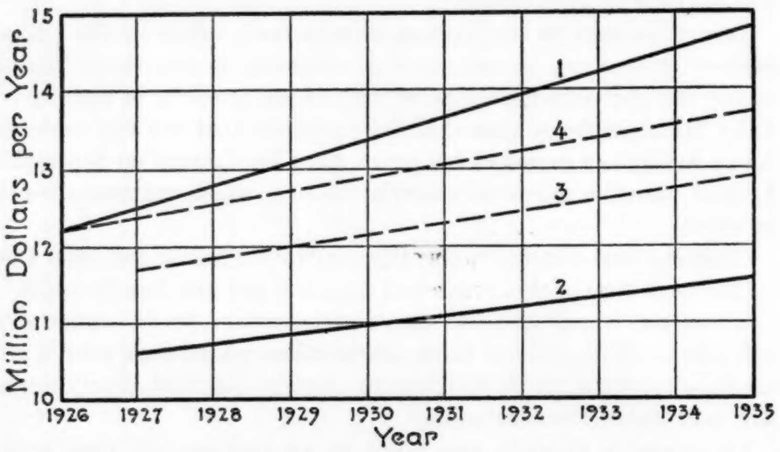

FIG. 5. 1. Total expenditures unmetered plan; exclusive of sinking fund and interest, estimated from part trend.

2. Expenditures under metered plan, exclusive of sinding fund and interest, and also exclusive of cost of meter installation. Taken from estimates made when meter ordinance passed.

3. Total cost under metered plan, estimating cost of meters installed at $30.00 each avrage.

4. Total cost under metered plan, estimating cost of meters installed at $50.00 each average.

the Machinists' Union, who also have their particular rules and regulations.

These conditions, especially in a large city where Unionism is strong, make it rather difficult to carry on certain work under ideal arrangements.

The setting of meters proper, which has heretofore been done by meter setters employed in the meter shop, is now, since the passing of the universal meter ordinances, claimed by the plumbers. There is, therefore, a situation that is not conducive to the most desirable

and economical method of operation in carrying out our metering program.

The work under the new ordinance has thus been under way for some three months with more or less unsatisfactory results. Unless material improvement in the carrying on of this work is shown the cost of metering the Chicago System will considerably exceed the estimates as made previous to starting the work, and, besides, will probably delay the work. We are in hopes that as the work progresses a satisfactory solution of these matters will be found.

There is, of course, a limit to the expense one is warranted in going to even in the case of such an exceedingly important matter.

In figure 5 the expenditures are shown estimated for the future under the conditions prevailing up to the present time and also various assumed costs of metering. As far as Chicago is concerned, it can be seen that even a doubling of the cost of metering, as was estimated, would warrant its adoption.

Excessive cost of metering would naturally cause one to look for some other possible and practicable means of gaining the object sought. Some years after the first earnest effort was made in 1901 to have a universal meter ordinance passed in Chicago an appropriation was made for rather extensive pitometer surveys with house to house inspections and accompanying plumbing repairs. While some good and much needed results were obtained by this method of stopping leaks and waste, the advantages gained were not permanent, but in two or three years the situation, as far as plumbing leaks were concerned, seemed to be as bad as before. At that time considerable street leakage was found to exist, especially in the old district of Chicago and in some annexed districts. These districts have since been generally overhauled. Much stress is laid by opponents of metering on the conditions as then obtained, and in general arguments are made that underground leaks in mains are the main cause of unsatisfactory services, and should be stopped before metering is resorted to, and that leak surveys, with following up repairs, is the proper remedy. This may be true to some extent in some places, but without metering the inequality in distributing charges for service will continue, and the location of leaks in mains is much facilitated where there is a metered system.

During the past ten years the City of Chicago in all cases of paving new and repaving old streets makes a thorough leak survey and repairs all leaks, where found, to be eliminated before a new pave-

ment is laid. Of course, where leaks appear on the surface or wherever otherwise found, such are always attended to in the regular course of work.

So far about 20 per cent of the entire pipe mileage in Chicago has been surveyed in connection with paving work.

A map in the City Engineer's office indicates in red lines the pipes which have been thus tested and attended to. This map shows a quite even distribution of such mains in all districts of the city. The average result of these surveys indicates a street leakage in the distribution system of not to exceed 6 per cent of the total pumpage. On first test 67 per cent of all mains so tested were found to be practically tight. Tests of mains are also made in connection with the new meter installation program. Along with the metering operations in Hegewisch, before referred to, a survey was made to locate and stop the underground leakage. There were 7.65 miles of mains, 6, 8 and 12 inches in diameter, thus tested, and an underground leakage of 32,500 gallons per day was located and stopped. Based on the total flow into Hedgewisch, previous to metering, this underground leakage amounted to only 1.2 per cent.

Under these circumstances, it seem that the substitution of pitometer surveys for metering on the plea of excessive underground leakage would not be advisable in Chicago, although an important advisable adjunct in connection with the meter installation work.

Such pitometer work is ably taken care of by an experienced Engineering Section of the Water Pipe Extension Division. The efficient and valuable work, besides the pitometer surveys, that is performed by this Engineering Section under Mr. J. B. Eddy, could be a subject for a paper that would interest any water works official. I hope that Mr. Eddy some time will favor this Association with such a paper.

RESPONSIBILITY OF MUNICIPALITIES, WATER COMPANIES AND INDIVIDUALS FOR WATER-BORNE ILLNESS[1]

By Isaac D. Rawlings[2] and Harry F. Ferguson[3]

Although water-borne epidemics, and the cause, prevention and responsibility therefor, have been chronicled before this Section and at other meetings of waterworks associations, and have been printed in the Journal and other publications, it nevertheless seems worth while again to write and talk on this subject because four preventable water-borne epidemics occurred in Illinois last year and the Attorney General has recently rendered an opinion as to the responsibilities of municipalities, water companies, and individuals for water-borne illness. When human beings are being made ill, lives are being sacrificed, and fairly large economic losses are occurring because of contaminated water, repeated reference to the cause, prevention, and responsibility for such illness, loss of life, and economic loss seems warranted until we have all learned the lesson and are guided thereby in our daily work.

All four water-borne epidemics in Illinois last year, which totaled several thousand cases of more or less severe illness and several deaths, would have been prevented if the warnings and recommendations of the State Department of Public Health that had been given to each city or water company had been heeded and followed. Therefore, although the department feels that it had done everything that it could under existing laws to prevent these epidemics, there is little or no satisfaction in being able to say "I told you so," when it is realized that human beings have suffered and economic losses have occurred. In days gone by, the suppression of epidemics took a considerable part of the time, effort, and finances of health departments, but with present knowledge of sanitary science there is no need of water-borne illness and epidemics if such knowledge is applied.

[1] Presented before the Illinois Section meeting, March 24, 1926.

[2] Director, State Department of Public Health, Springfield, Ill.

[3] Chief Sanitary Engineer, State Department of Public Health, Springfield, Ill.

One health worker has said "Cure is the voice of the past; prevention the work of the future."

Of the four water-borne epidemics in Illinois during 1925 one was caused by the pollution of the water after being drawn from wells, another by underground pollution of water in a well, another by the contamination of a drinking-water supply through a cross-connection with a piping system carrying a polluted industrial water supply, and the fourth by the inadequate purification of a surface-water supply.

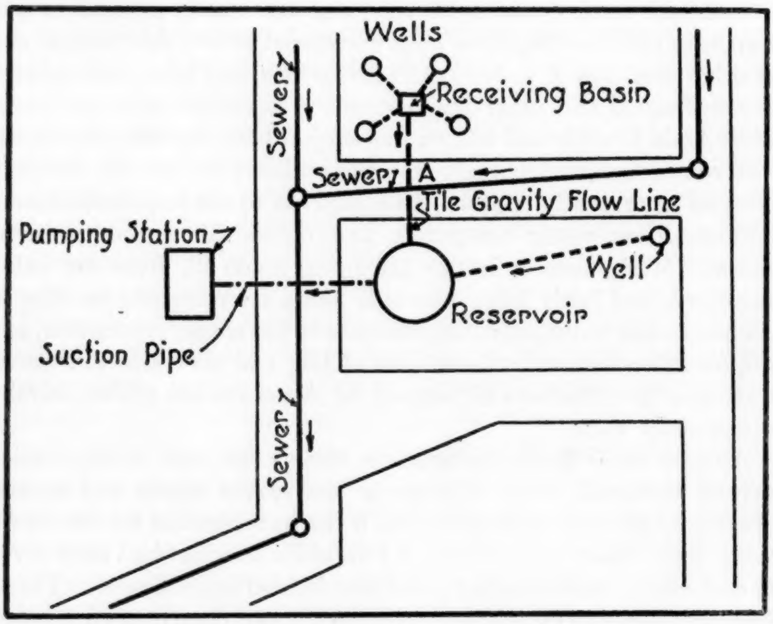

FIG. 1. PIPING IN VICINITY OF GREENVILLE WATERWORKS

The leakage of the sewer into the tile water line occurred at *A*

GREENVILLE

The water supply at Greenville is obtained from several tubular wells ending in sand and gravel. The water from a group of four wells was pumped into a receiving basin from which it flowed by gravity through a pipe line built of vitrified tile with cemented joints to a collecting and storage reservoir across a street from the field in which the wells were located. In that street there was a tile sewer which passed about one foot below the tile water pipe. Figures

1 and 2 show the Greenville situation. In January 1925, there occurred an explosive epidemic of dysentery and paratyphoid fever. Of the entire population of 3000 very few persons escaped the illness, and in addition quite a number of people from the surrounding farms and travellers visiting or stopping at Greenville for a meal were made ill. Investigation showed that the sewer had become clogged and that sewage was flowing through the tile water line into the collecting and storage reservoir from which the water was pumped direct to the city without any treatment. No analyses were necessary to prove

FIG. 2. "LOCKING THE DOOR AFTER THE HORSE WAS STOLEN." CHANGING THE PIPING THAT PERMITTED POLLUTION OF THE GREENVILLE PUBLIC WATER SUPPLY

the pollution of the water in the collecting reservoir. The nose was sufficient.

About two years before the epidemic at Greenville, the danger of this sewer becoming clogged and the sewage from it backing up and seeping into the water tile line had been pointed out verbally and by letter to the mayor and council of the city, together with six other dangerous or unsatisfactory conditions in the waterworks system. About two months previous to the epidemic the dangers and defects in the waterworks system were again pointed out verbally to the city

officials when it was found that previous warnings and recommendations had not been heeded and followed. Only after the epidemic

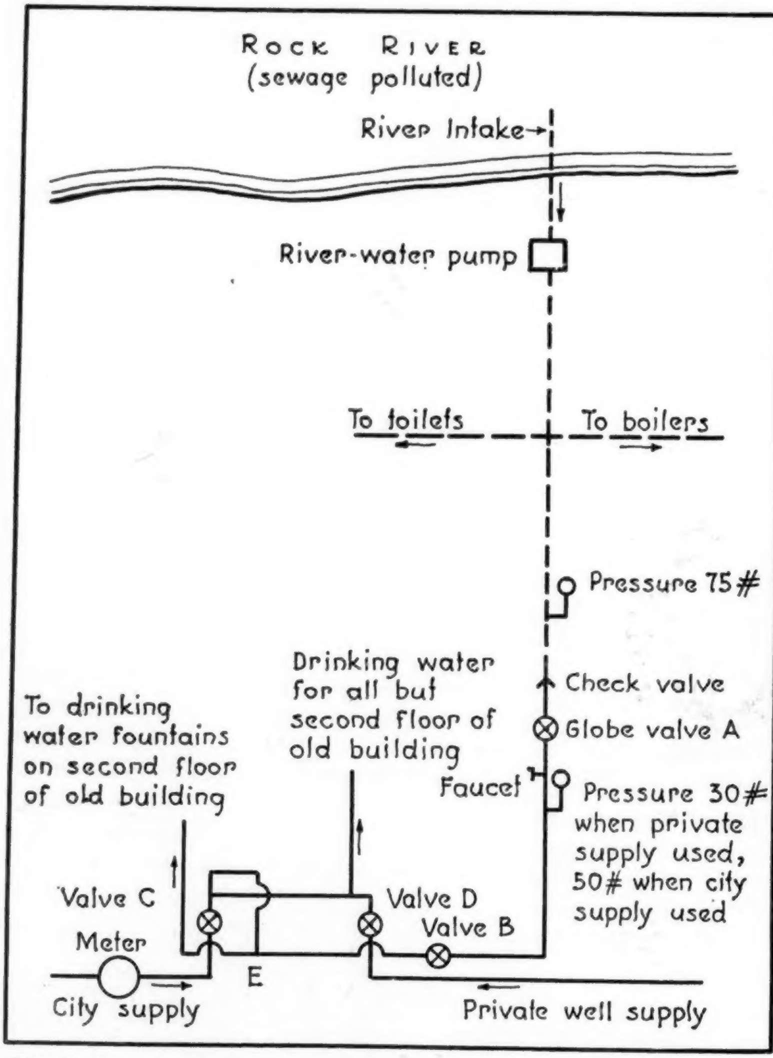

FIG. 3. ARRANGEMENT OF WATER PIPING AT FACTORY AT STERLING THAT PERMITTED CONTAMINATION OF DRINKING-WATER SUPPLY

did the city become alarmed over its water supply. Then some persons wanted to abandon all wells and everything and obtain an entirely new waterworks. The city is now making changes and

improvements, but unfortunately is still proceeding in a somewhat hit-and-miss plan without experienced engineering advice and supervision.

STERLING AND ROCK FALLS

The water-borne typhoid fever which occurred at Sterling and Rock Falls (adjoining cities served by the same water supply) comprised 12 cases and at least 2 deaths. All cases were employees of one factory. There was a cross-connection between the piping system carrying the drinking water and the piping system carrying the sewage-polluted Rock River water for industrial use and the control valve leaked as all valves may sooner or later. Figures 3 and 4 show the layout of the piping and the cross-connection. All persons that were ill worked on the second floor of what was known as the "old building," whereas the same drinking-water-supply system of piping extended to other floors and other buildings. A study of the hydraulics of the piping showed that with the limited amount of leakage through the valve controlling the cross-connection and normal consumption at the different points the polluted water would go to the second floor of the old building where the people worked who were sick.

Previous to the local realization of the cause of this typhoid fever there were two cross-connections at the waterworks pumping station, which is owned and operated by a private company. Formerly there had been four cross-connections or emergency suction connections, two of which had been abandoned after repeated recommendations from the State Department of Public Health, but the company seemed adverse to removing the other two. It took water-borne illness and deaths in their own city to make the water company officials realize that, if similar pollution should result in the water supply because of the cross-connections at their own pumping station, even a more disastrous epidemic through Sterling and Rock Falls would occur.

LOCKPORT

The typhoid epidemic at Lockport comprised fifteen cases and at least three deaths. There is some uncertainty as to whether this epidemic was caused by the public water supply or the water supply at a factory. The cause of the illness is now before the court so our opinion is not stated here. Both the public and the factory water

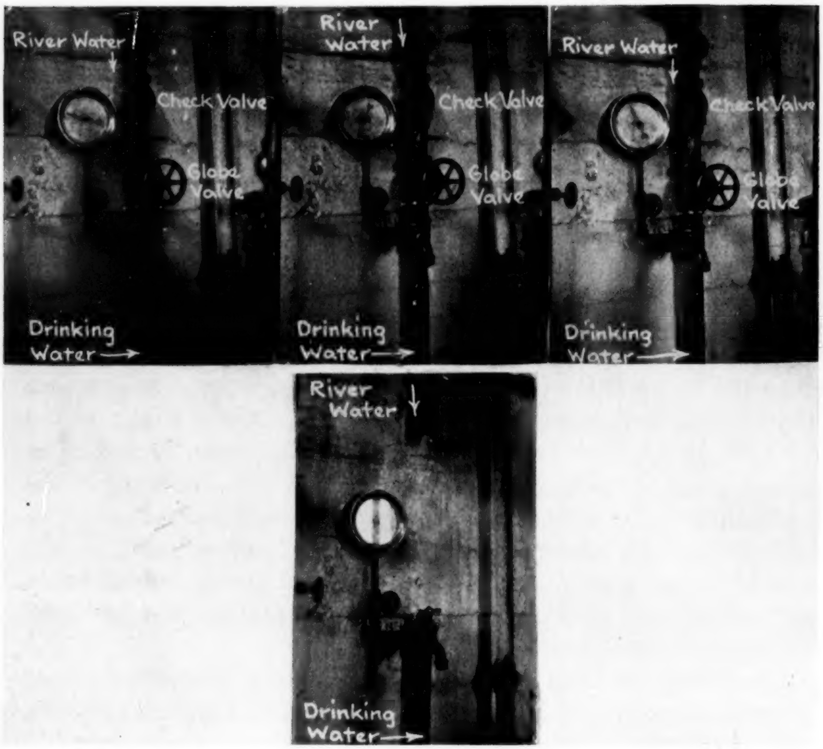

FIG. 4. These pictures show the arrangement of pipes and valves that connected a polluted river-water supply with a drinking-water supply in the factory at Sterling. The river water entered the pipe at the top and the drinking water the pipe at the bottom. The two kinds of water were supposed to be kept separate by the check and globe valves. These valves leaked as all valves do or may sooner or later, thus polluting the drinking water. The pictures also show tests that were made to prove that leakage was taking place. In the upper left picture the globe valve was closed and a valve which is not shown on the drinking-water line was left open, the gage thus registering the pressure in the drinking-water system. In the upper center picture the river-water valves shown, and the drinking-water valve not shown were closed and the faucet between the two sets of valves was opened in order to drain that portion of the pipe. The gage registers zero. In the upper left picture the faucet had been closed, thus leaving all the valves closed. The pressure as registered by the gage increased to the pressure prevailing in the river-water system, thus proving that the check and globe valves controlling the river-water supply were leaking. The lower picture shows how the cross connection between the river-water and drinking-water supplies has been abandoned by removing a section of the pipe.

supplies are obtained from wells ending in creviced limestone and analyses had shown both supplies to be of questionable or dangerous quality. The State Department of Public Health had repeatedly recommended chlorination of the water because of the character of the limestone from which the water is obtained, the proximity of sources of pollution such as sewers, privies, cesspools, and also the sewage-polluted Chicago Sanitary District drainage canal. It took the epidemic to make the city realize that the warnings of the department were sound, because the city purchased a chlorinator during the epidemic.

CHARLESTON

The epidemic caused by an inadequately purified surface supply was at Charleston. The treatment plant was installed about 1912, but has never been so maintained and operated as to produce a constantly clear, clean water and one that is assuredly safe. Notwithstanding the fact that thousands of dollars have been invested in that treatment plant the water in the mains has been sufficiently turbid and dirty at times that water meters would not operate properly. The city has had one or more cases of typhoid fever practically every month for the past few years, many of which have very probably been caused by the public water supply.

In November 1925, there occurred an explosive epidemic of diarrhea. Probably at least one person in every four in that city of a population of 8000 was affected, including those attending the Eastern Illinois State Normal School. Some people thought or endeavored to spread the idea that the epidemic was influenza of the intestinal type, but epidemiological data assembled by the department's medical staff combined with the circumstantial and other data relative to the public waterworks showed conclusively that the public water supply was responsible for the majority of the illness, although there probably were cases of colds, grippe, etc. in the city at the same time.

Many visits, reports, letters, warnings, and recommendations had been made to the city officials of Charleston during the past several years, but this city unfortunately has so mismanaged and badly operated its waterworks that not only the physical and sanitary quality of the water has been unsatisfactory and dangerous, but the operating efficiency has been low, the operating costs high, and the charge made to the consumers for water one of the highest, if not the highest, in the State.

The department's warnings and recommendations and the lessons taught by past water-borne epidemics are heeded by some and, therefore, though we do continue to have water-borne epidemics, they are less frequent than would be the case if we did not learn from the sad experience at other places. As one instance a water company may be mentioned which learning, through an item sent out by the department, of the Sterling epidemic that was caused by a cross-connection became immediately concerned over a cross-connection that existed in a railroad yard which it supplied with water. It is interesting to note that the cross-connection existing in that railroad yard was very similar to the cross-connection which existed in the Chicago and Alton Railroad yards at Bloomington in 1919, which caused an epidemic of several hundred cases of diarrhea, about 200 cases of typhoid fever, and 15 to 20 deaths. The water company has taken action to have the cross-connection abandoned between its own water-supply system and the railroad's private supply system which obtains water from a sewage-polluted ditch.

If the advice and warnings of the department had been followed the four epidemics related above would not have occurred, and needless suffering, loss of life and economic loss would have been prevented, but the department would have had nothing tangible to show for its efforts. If an engineer designs an attractive water-treatment plant he can point to his work with pride, and the results of his work are visible to all. Those engaged directly in health work realize the value of "prevention," but it is one of the possibly discouraging phases of health work that for the best work that is done there is no good way to show the results or at least to make those results known to the average person who pays taxes or in other ways contributes toward health departments. Dry, uninteresting, statistical figures as to the number of cases and deaths and the gradual decline in the preventable diseases such as typhoid fever are all that can be pointed to by the health worker.

RESPONSIBILITY FOR WATER BORNE DISEASE

We have stated that certain diseases are preventable. We have stated that the above recorded four epidemics could have been prevented. Such being the case we may ask "Who is responsible for these epidemics and similar ones if they unfortunately occur in the future?" A little over two years ago there occurred a wreck of the Twentieth Century Limited, the crack New York Central train,

which gained headlines in the press throughout the country. It was a disaster, but only a comparatively few people were killed or injured as compared to the number of people that have been killed or injured by water-borne illness. Investigations were made to determine the cause and place the responsibility for the wreck. If a few people in an automobile are killed, the community in which such happens is aroused and nearly everyone reads the details in the papers with great interest. The coroner makes an investigation and places the blame. If a person, mentally unbalanced, kills or maims a person with a bullet or other weapon, the community in which such occurred would be very much aroused. And yet, in similar communities deaths have occurred and still do occur by the furnishing of drinking water that is not safe.

Why should a person or persons who are responsible for furnishing safe drinking water permit, by neglect, carelessness or deliberate indifference, polluted water to go through piping systems which they know human beings are to use for drinking water? An epidemic of disease is not quite as spectacular as a train wreck or a murder by bullets, but they cause greater suffering, greater loss, and are the least excusable because they can be prevented.

Some of you have perhaps read in the pages in the Manual of Water Works Practice published by the American Water Works Association, the quotations from court decisions dealing with damage suits and responsibility for water-borne epidemics. No court decisions have been rendered in Illinois, but the Attorney General of Illinois in a recent opinion to the State Department of Public Health points out that the law on the basis of court decisions in other States recognizes the responsibilities of cities, water companies, and individuals furnishing water for general use. Believing that the Attorney General's opinion would or should be of interest to waterworks officials in Illinois it is quoted below in full as follows:

You have requested my opinion on the liability of a municipality or water company for disease resulting from pollution of water furnished the inhabitants of the municipality, under the conditions assumed in three questions. The first of said questions is as follows:

"1. If a public water supply should unquestionably cause typhoid fever or other water-borne illness and assuming that the supply was considered safe by the general consuming public and no advice or warning had been given by the proper officials would

a. A city or its officials be liable in case the city owned the supply?

b. A water company be liable in case a water company owned the public supply?

c. The city be liable if a public supply was owned by a private company and the city had not advised or warned the company of the dangerous conditions?"

Where a municipality acts in the dual capacity of furnishing water, gas or other commodity both for public and private use, under authority of law, it stands upon the same footing as would a private corporation or individual and is alike liable for its negligence or wrongful acts.

Village of Palestine v. Siler, 225 Ill. 630
City of Chicago v. Selz, Schwab & Co., 202 Ill. 550
Wagner v. City of Rock Island, 146 Ill. 154

The liability of a water company or individual supplying water for general use to the inhabitants of a municipality for injuries to health resulting from contamination of its water has not been declared by the courts of this State. Neither have our courts stated such liability of a municipality except in the general rule of the cases above cited and decisions of this question in other states are few.

In *Jones* v. *Mount Holly Water Company*, 87 N.J.L. 106, it was held that one who undertakes to trade in water and supply customers therewith is bound to use reasonable care that the water so supplied shall be ordinarily and reasonably pure and wholesome. Actual notice or knowledge of the unwholesomeness of the water of such company is not an essential element to be proven in order to establish defendant's liability; it is sufficient if there is testimony tending to show that the defendant in the exercise of reasonable care might have discovered the unwholesomeness and dangerous condition of the water.

In *Hayes* v. *Torrington*, 88 Conn. 609, it was said:

"The duty which a water company owes to the public and to its customers is that of exercising reasonable care and diligence in providing an adequate supply of wholesome water at all times. Dillon on Municipal Corp. (5th Ed.) Sec. 1316; *Green* v. *Ashland Water Co.*, 101 Wisc. 258; *Danaher* v. *Brooklyn*, 119 N. Y. 241; *New Haven Water Co.* v. *Russell*, 86 Conn. 361. Such a corporation is not a guarantor of the purity of its water or of its freedom from infection, but is bound to use reasonable care in ascertaining whether there is a reasonable probability that its water supply may be infected with a communicable disease from causes which are known to exist, or which could have been known or foreseen by the exercise of reasonable care; and if the exercise of such care would have disclosed a reasonable probability of such infection, then it becomes the duty of the water company to adopt whatever approved precautionary measures are, under the circumstances of the case, reasonable proper and necessary to protect the community which it serves from the risk of infection."

In *Green* v. *Ashland Water Co.*, 101 Wisc. 258, it was held that a distributor of water under a public franchise is not a guarantor or insurer of the wholesomeness of his water. But such distributor will be held liable for injury to consumers, without fault on their part from using the water furnished where such distributor knows, or from the situation ought to know, that the water it is distributing is dangerous for domestic use from some cause not discoverable ordinarily by the use of reasonable care, and failed to disclose such danger

to such consumers. But it was also held that where the contaminated and dangerous condition of the water is a matter of common knowledge in the community, the presumption is that a member of the community of ordinary intelligence has notice of that condition of the water, and, in the absence of evidence to the contrary, that presumption will preclude a recovery by a person injured from using such water. If a person drinks water furnished by such company with knowledge, or reasonable means of knowledge, that it is dangerously polluted with sewage, he assumes the risk and can not recover on the ground of deceit or negligence.

In *Keever* v. *Mankato*, 113 Minn. 55, it was held that where a city owns and controls its water work system from which it furnishes water for the general use of its inhabitants, the city will be liable for negligence in permitting its water supply to become so contaminated that it causes typhoid fever.

Applying the rules of liability above declared to subdivision (a) of your first question, I think it clear that the city would be liable if its officials in charge of the water supply actually knew the dangerous condition assumed by your question, or by the exercise of reasonable care should have known it, and failed to give public warning thereof.

Answering subdivision (b) of your question, the water company would be liable if it knew, or by the exercise of reasonable care should have known, that the water supply was contaminated as aforesaid and did not warn its consumers of such condition.

Subdivision (c) of your question is whether the city would be liable if the public supply was owned by a private company and the city had not warned the company of the dangerous condition assumed by your question. To hold that the city is liable because it fails to notify the water company of that which such company already knows, or in the exercise of reasonable care should know, would be in effect to make the city liable for the negligence of the water company. I have found no case or text writer which goes to that extent. The efficacy of such warning given by the city to the water company to prevent illness as a result of using contaminated water furnished by the company would seem too uncertain to render the city liable for failure to give such warning, even where the company does not know the dangerous condition of the water. I am not aware of any statute or decision upon which the liability of the city under such conditions may be reasonably predicated.

Your second question is as follows:

"2. Would the responsibility and your opinions be changed if the State Department of Public Health had given due warning in writing to a city in case the city owned the supply, and to the water company and city in case the water company owned the supply, that the supply was subject to possible contamination and thereupon the city or water company or either or both did not act to remove such possible contamination or did not advise or warn the consuming public of the dangerous conditions while the dangers were being removed?"

Such warning would not be conclusive of the liability of either the city owning the water supply or of the water company owning it; but would be a fact strongly tending to show that the city or company knew or should have known the conditions of which it was warned, by putting it on notice thereof,

and to establish negligence of the city or company in failing to remove the possibility of contamination or to warn the public of the dangerous conditions set forth in such warning by the health department.

Your third question is as follows:

"3. Would a verbal statement by a representative of the State Department of Public Health, while carrying out his regular duties, that the public water supply is subject to contamination constitute a sufficient warning to city officials or a water company so that such city or water company would be liable in case dangerous contamination of the water supply did occur and water-borne illness resulted?"

In the absence of a statute requiring written notice of a state of facts assumed by your question, I think a verbal statement would be as efficient as a written statement where the proof that such verbal statement was made and the contents thereof to the proper representative of the city or water company is clear and satisfactory.

Summarizing the Attorney General's opinion we conclude that cities, water companies, and individuals supplying water for general use are liable for injuries to health resulting from contamination of such waters if the owners or operators of such water supplies have not exercised reasonable care in discovering and preventing possible contamination of the supplies or have not given due warning to the consumers that the supplies are subject to dangerous contamination. Further that a warning by the State Department of Public Health to a city, water company, or individual distributing a water supply, which supply causes injuries to health, would not be conclusive of the liability of such city, company or individual, but it would be a fact strongly tending to show that the owner of the supply knew of the dangerous conditions and would, therefore, practically establish the negligence of the city, company, or individual in failing to remove or prevent the contamination of the supply or to warn the public of the dangerous condition.

Illness that is water-borne in Illinois can be prevented, but only will be prevented when all of us realize our responsibilities and when those owning and operating waterworks systems exercise reasonable care and diligence. On the basis of the Attorney General's decision the next water-borne epidemic in Illinois, if another unfortunately does occur, may prove quite costly to the owners of the waterworks system.

EXPERIENCE WITH CEMENT-LINED CAST IRON PIPE[1]

By J. E. Gibson[2]

Cement has been used for lining thin shelled wrought iron or steel pipe a long time. As early as 1865, and probably earlier, this kind of pipe was made under United States patent by Finius Ball, George H. Norman, and others, and this pipe is still being used by a number of water works plants in New England. The Philadelphia Suburban Water Company has over five hundred miles of this type of pipe manufactured under patents granted Dr. D. Goffe Phipps, Hydraulic Engineer of Bridgeport, Conn. A most excellent paper on this subject by Leonard Metcalf appears in the New England Water Works Association Proceedings of March, 1909.

Cement-lined cast iron bell and spigot pipe was, I think, first used in Charleston by the writer in 1922, although at about the same time this same kind of pipe was being made in England. Since that date considerable of this pipe has been laid. In Charleston, we have laid upwards of twenty-five miles, and there are a number of other plants, throughout sections of the United States, where filtered water of aggressive or active type is prevalent, using cement-lined pipe.

At first the process of lining was the same as that used for lining the thin shelled wrought iron pipe first referred to; namely, by the up-ending of the pipe and the placing of a projectile shaped bullet or trowel in the bottom, placing the necessary amount of natural cement mortar into the pipe and on top of the projectile, and then drawing the projectile rapidly through the pipe, the cone or projectile shaped end acting as a trowel to force the cement mortar out against the walls of the pipe. Great care had to be exercised to see that the mortar was properly mixed, had the requisite amount of water, and proper setting qualities so that the lining would not bag or run after the bullet had been pulled through.

[1] Presented before the Joint Meetings of the Plant Management and Operation and Fire Protection Divisions, Buffalo Convention, June 11, 1926.

[2] Manager and Engineer, Water Department, Charleston, S. C.

The thickness of the lining by this process was about $\frac{3}{16}$ inch for the 4 to 10 inch pipe, and $\frac{1}{4}$ inch for 12 inch and above.

This process of lining was in use only a short while when it was supplanted by the centrifugal method, and Portland cement with a small percentage of sand was substituted for the natural or Rosendale cement. The process of lining centrifugally consists of placing the pipe on a pair of trunnions and revolving it at the rate of about 300 revolutions per minute. The mortar consists of any good grade of American Portland cement with 20 to 30 per cent of clean, sharp sand passing a No. 20 mesh screen, mixed preferably in a mechanical mixer, and then introduced into the pipe. The mortar is introduced into the pipe which is to be lined by the use of a gauge formed by splitting a 2 inch pipe about along its longitudinal center line, the requisite quantity of cement having been previously measured out and placed in the 2 inch split pipe for its entire length. As soon as the pipe has reached the proper speed, the mortar is emptied from the container or trowel pipe by turning it over and then distributed over the inner surface of the pipe by using the gauge pipe as a trowel. The size of the trowel pipe is determined by the quantity of mortar required for the desired thickness of lining and the size of the pipe which is to be lined. Care must be used to distribute the mortar equally over the surface of the pipe and to cover entirely the surface of the pipe. As soon as the mortar is equally distributed, the gauge pipe is removed, and the speed of the pipe is increased, and its revolution on the trunnion, due to the roughness of the outside, gives a tamping effect, which effectively brings the water to the inner surface of the mortar and drives out any entrained air, giving an intimate contact between the mortar and the walls of the pipe. The work, if properly done, gives a very smooth, semi-porcelain like lining which sets up very rapidly, permitting the pipe to be removed within a few minutes from the lining machine to the storage yards.

Portland cement being superior to the natural or Rosendale cement, it was believed that the thickness of the lining could be materially reduced, and this was done. The lining was tentatively adopted as $\frac{1}{16}$ inch for all pipe from 3 to 24 inches diameter, with a tolerance of $\frac{1}{32}$ inch. It was found, however, that this was too thin (of which notice will be taken later), and recently we have changed our specifications to require $\frac{1}{8}$ inch for pipe from 3 to 16 inches in diameter and $\frac{1}{4}$ inch for pipe above 16 inch in diameter, with a tolerance of $\frac{1}{16}$ inch.

In the old process, where the projectile bullet type of lining was used, it was found that the eccentricity of the pipe or deflection in its length did not materially affect the thickness of the lining, as the bullet was on a flexible rope and the mortar tended to hold it in the center of the pipe without regard to whether the pipe was straight or not; but with the centrifugal method of lining, it is found that if the pipe is out of round or not straight, the lining tends to take the centrifugal center so that the lining is at times eccentric; that is, much thinner on one side than on the opposite side. This is overcome where the lining is placed in a centrifugal type casting such as the deLavaud, Mono-cast, and sand spun cast pipes.

It is naturally our desire to leave a favorable feeling toward cement-lined pipe, but we would be failing in our duty to the users if we did not call to their attention some of the difficulties experienced with linings that were too thin.

Naturally, in making any form of castings, it is impossible to obtain a perfectly smooth finish; in fact, we feel that too smooth a surface is far from being desirable when it is intended to cement-line the castings. If the interior surface of a cast iron pipe before lined or coated were inspected by means of a microscope, it would probably resemble very much the "bad-lands of the Dakotas" as to roughness. This offers an admirable condition for the adhesion of the cement mortar to the surface of the pipe, but unfortunately, some of these pimples extend further from the surface than others, and when we attempted to make a thin lining—$\frac{1}{16}$ inch with a tolerance of $\frac{1}{32}$ inch—it was found that a lot of these pinnacles protruded through the lining and immediately began to form tubercles. Again, in some cases referred to, the lining became eccentric, and instead of having an average of $\frac{1}{16}$ inch thickness throughout, it was reduced almost to the thickness of paper on one side of the pipe, abnormally thick on the opposite side, with the result that more pinnacles projected through on the thin side than on the other. As a rule, however, the rusting took place on top of the pinnacles, forming a mushroom over the lining, and did not force the lining off; so notwithstanding the fact that perfect protection was not obtained, we feel that it was much better than that afforded by the old tar coating as we know it. Where all the pinnacles were protected with a lining of cement, however thin, tuberculation or rusting did not occur so far as we have been able to observe.

By increasing the thickness of lining to $\frac{1}{8}$ inch with a tolerance of

$\frac{1}{32}$ inch, which would give ordinarily a minimum thickness of $\frac{3}{32}$ inch, we are confident that no pinnacles will protrude, and that the carrying capacity of the pipe will be maintained indefinitely.

The first cement-lined pipe laid by the Charleston Water Department was in the fall of 1922, and tests made of some 6 and 16 inch pipe, lined by the method first employed using natural cement, gave values of "C" in Hazen's and Williams' formula varying from 128 to 141 in the case of the 6 inch pipe, and tests made of the 16 inch pipe a year later gave a value varying from 127 to 133. In the test on the 6 inch pipe, the quantity of water flowing was measured by means of a standard Crest type meter, and in the case of the 16 inch test, by pitometer. The friction losses were measured by means of U tubes, using carbon tetrachloride for the lower loss of heads and mercury for the higher. Piezometric pipes were run between points of measurement so that all instruments were located at one point in order that errors would be reduced to the minimum. All results are based upon 32 observations (the number of observations at each test) and average taken of all.

In 1924, we laid some 6 inch pipe lined with Portland cement by the centrifugal process. Tests made immediately after laying this pipe gave values for "C" in Hazen's and Williams' formula of 125 to 146, with velocities from 1.25 to 5.5 feet per second. In this last series of tests, the first two tests were made using carbon tetrachloride at $1\frac{1}{2}$ specific gravity, and considerable trouble was had with fluctuations in the manometer tube. You all appreciate how hard it is to get readings of a manometer when the liquid in the two legs is fluctuating violently. The average of all readings gave a value of 137 and omitting the first two readings, the average value was 144. Tests made this past May (practically two years later) on this same pipe covering a range of velocity from 0.9 to 4.8 feet per second, gave an average value of "C" in Hazen's and Williams' formula of 139 with a minimum of 134 and a maximum of 145. This shows the minimum to have been 96 per cent of the average and the maximum 104 per cent of the average, and the results as compared with the former test, including the two first tests, were 96.5 per cent and excluding the first two tests, 102 per cent. Sample of this pipe which has now been in use for two years is here on exhibit for the members to see. This pipe was broken out the line to insert a Tee and special to connect up meters for measuring the quantity of water discharged.

Our conclusion in the matter is that for a filtered water supply of a peaty or aggressive nature, cement-lining offers a wonderful improvement over ordinary tar-coated pipe in that it will maintain its carrying capacity indefinitely. While tests covering pipe only a few years old, such as the above, are not conclusive in themselves, inspection and tests made on the old wrought iron shell cement-lined pipe first referred to in this paper, which has been in the ground from twenty-five to fifty years under similar waters, shows no incrustation. Since cast iron pipe under the same circumstances shows a loss in capacity of anywhere from 20 to 80 per cent, it is indicative that similar conditions will be maintained in the cast iron cement-lined pipe.

Needless to say, where it is intended to line cast iron pipe, it should not be tar-coated. Some engineers in specifying a cement-lined pipe have insisted upon its being tar-coated on the outside, which adds to the expense. Upon investigation, I have reached the conclusion that the coating on the outside of the pipe is really an incidental matter, as Dr. Angus Smith, the original inventor of the tar coating, was attempting to protect the interior of the pipe from tuberculation and incrustation. It was found that to dip the entire pipe was a cheaper process than to apply the coating in any other way, and of course, this process coated the outside as well as the inside. Further, none of the gas companies so far as we can learn ever attempt to coat their cast iron mains on the outside and depend upon the natural protection of the gas with the entrained oils and tar for the protection inside. The life of their pipe seemed to be as great as that of the water pipe, so we reached the conclusion that it was not necessary to go to the expense of attempting to tar-coat the outside of our water pipe and have not in the past four years laid any cement-lined pipe with outside protective coating.

Malcolm Pirnie, consulting engineer for the West Palm Beach Water Company, has laid considerable cement-lined pipe in recent years and has had some trouble due to the lining being too thin and the pinnacles of iron protruding through the lining, which condition I have already referred to. While we have experienced no complaint ourselves, it has come to our notice that somewhere in New England they had complaint of discoloration of alumium vessels from water that was drawn from cement-lined pipe.

In closing I would refer you to the paper by Leonard Metcalf in the Journal of the New England Water Works Association of March,

1909; also paper by Charles W. Sherman on Cement-Lined Cast Iron Pipe in the Journal of the New England Water Works Association on March, 1926; the annual reports of the Commissioners of Public Works, Water Department, Charleston, S. C., for the years 1923 and 1924; and a paper by me in Engineering News-Record of September, 7, 1922, Volume 89, No. 10.

FIG. 1. LINING MADE BY "BALL" OR "BULLET" METHOD, USING "NATURAL" CEMENT

This lining varied in thickness from $\frac{1}{32}$ to $\frac{3}{16}$ inch. (Magnification by ten diameters.)

DISCUSSION

H. Y. CARSON:[3] Mr. Gibson's able presentation is a good résumé of the experience with cement lined cast iron pipe since he started its use in Charleston, South Carolina, in 1922.

This development or improvement is, of course, one in which the makers of cast iron pipe are very greatly interested, because it has

[3] Research Engineer, American Cast Iron Pipe Co., Birmingham, Ala.

yielded an acceptable solution of an old water works problem, increasing the durability and service value of cast iron pipe, and above all, preventing a loss of capacity through tuberculation. The greater assurance of maintaining a high flow that will not decrease over a period of many years is extremely important.

FIG. 2. SPECIMEN OF SAME TYPE OF CEMENT LINING USED IN PIPE AT DANVERS, MASSACHUSETTS, FOR THIRTY-NINE YEARS, THREE MONTHS

This lining was exceedingly smooth when first removed but upon drying in air shows a porous outer shell $\frac{1}{64}$ inch thick (the dark portion) which was easily crumbled and detached from underlying structure. (Magnification by ten diameters.)

It is the speaker's opinion that the newly organized Committee of this Association whose duty it is to report on Cement-Lined Cast Iron Pipe will be of real service by recommending a standardized practice based upon the available information. Tentative specifications have already been prepared, and much has been done, but further exact knowledge will be needed in order to gain improvement.

Theoretical considerations indicate that only a very thin lining of cement is needed on the inside walls of cast iron pipe effectively

to keep down or prevent tuberculation. Practical considerations, however, dictate that an average thickness of $\frac{3}{32}$ inch is necessary, because a tolerance or variation in thickness of $\frac{1}{32}$ must be allowed for the eccentricity or other irregularities that normally occur in all pipe which are to be lined with cement. Perhaps other con-

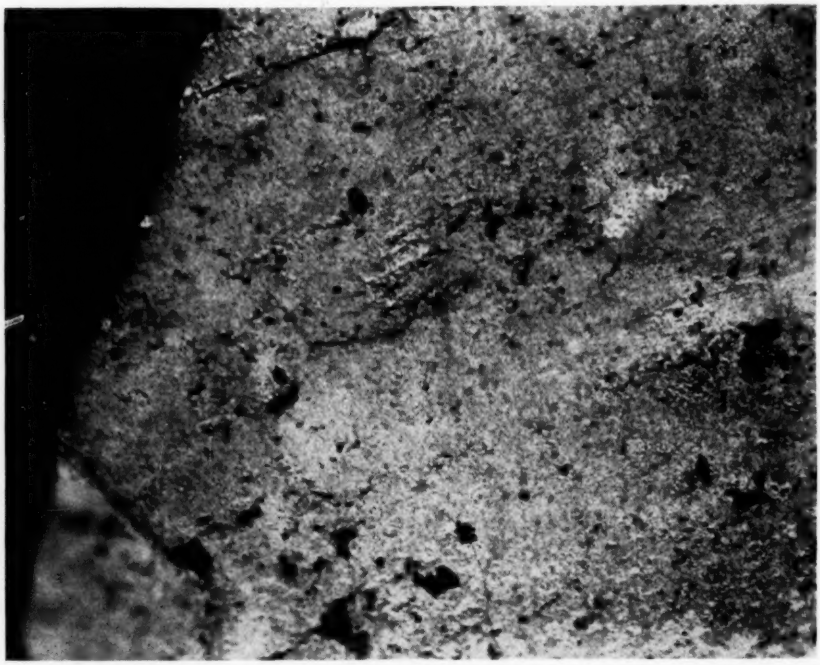

FIG. 3. CEMENT LINING MADE OF NEAT "NATURAL" ROSENDALE CEMENT $\frac{1}{2}$ INCH THICK, USED IN WATER LINES OF TALLAHASSEE, FLORIDA, FOR TWENTY YEARS

Note that outer surface is somewhat leached out the same as old lining from Danvers, Massachusetts. (Magnification by ten diameters.)

siderations are essential, such, for example as the ability of the water to dissolve away the cement over a long period of years.

It was with this last named thought in mind that the speaker made a careful study of linings under the microscope, and as some of the things found may be of interest they are here given.

The specimen, figure 1, shows a surface of a small section taken from a cement lined pipe made by using Rosendale (natural) cement which was applied by pulling a special trowelling device or ball

through the bore of the pipe and thereby placing a lining of neat cement varying in thickness at different points in the periphery of the pipe from $\frac{1}{32}$ to $\frac{1}{16}$ inch.

Some of this same type cement lined pipe had been used at Danvers, Mass., for thirty-nine years and three months, and when first

FIG. 4. CEMENT LINING BY $\frac{1}{8}$ INCH THICK APPLIED TO 20 INCH CAST IRON PIPE STRUCTURE

Of this lining 75 per cent is Atlas Portland Cement plus 25 per cent clean, sharp sand, made as per specification of West Palm Beach Water Company. Surface about the smoothness of porcelain. This lining was cured by covering ends of pipe with canvas and preventing loss of moisture during period of 24 hours. (Magnification by ten diameters.)

observed after removing from service the lining appeared to be smoother with old age. A chemical determination of various portions scraped from the lining showed it to have a slight increase in CO_3 content as compared to new linings, and moreover, the CO_3 content increased in the lining section as the wetted side of the cement was approached. The cement next to the metal of the pipe walls had apparently remained unchanged by time.

After this lining had become thoroughly dry in air, the outer shell about $\frac{1}{64}$ inch thick (see figure 2) had the appearance of shrinking or shriveling and even of detaching itself from the underlying cement structure. This underlying structure, although it had been in use for more than thirty-nine years, was apparently unaffected.

FIG. 5. CEMENT LINING BY $\frac{1}{16}$ INCH THICK, AS APPLIED TO 4 INCH CAST IRON PIPE

Structure of this lining is 75 per cent Atlas Portland Cement plus 25 per cent clean, sharp sand. This surface has a rougher feel to the hand than that shown in figure 4. Under the microscope we find small cavities which do not appear to the naked eye. These cavities probably caused by deficiency of water in cement at period of first hour after beginning to set. (Magnification by ten diameters.)

The outer $\frac{1}{64}$ inch shell is the part of the lining referred to above which showed by chemical analysis to have picked up CO_3 from the water and at the same time had given to the flowing water some which no doubt the water had dissolved. Possibly the soluble calcium hydroxide had been given up to the flowing water by the cement.

In figure 3 a sample of 4 inch cement pipe is shown which is in use at Tallahassee, Florida, for twenty years. This pipe was made and installed by the American Pipe and Construction Co. of Philadelphia, and the lining shown is $\frac{1}{2}$ inch made of neat Rosendale (natural) Cement. Like the specimen shown in figure 1 used at Danvers, Mass., it had been affected by the flowing water to a depth of about $\frac{1}{100}$ inch. It may be observed from the photograph that the Florida water did not discolor the outer surface of the cement as had the water in New England. Perhaps this can be explained by the difference in color between the two waters—that in New England being somewhat like tea.

Cement linings made centrifugally have not always been equally smooth in the outer texture of the surface as can be seen by examining figures 4 and 5. That shown in figure 4 is of about the same degree of smoothness as ordinary porcelain, and is at present typical of the lining described by Mr. Gibson as being used at Charleston, South Carolina, and by Mr. Pirnie as being used at West Palm Beach, Fla.

In conclusion, the speaker repeatedly finds that in the unfiltered municipal water supplies the acid, or other dissolving properties of the water, has not damaged the cement linings to any marked extent. We do not know, of course, what new conditions may be imposed by pumping filtered and chlorinated water into the cement lined distributing mains, but to be on the side of reasonable safety it would seem wise (at least until proved otherwise) to use cement linings which have a minimum thickness of $\frac{3}{32}$ inch. This means that the specified average thickness must be $\frac{1}{8}$ inch as brought out in Mr. Gibson's paper.

A COMPARISON OF SERVICE PIPE MATERIAL[1]

By O. B. Mueller[2]

One of the basic reasons for all great strides in modern science, invention and commerce is the gaining of more knowledge about the materials we use., And only second to the value of invention and discovery of new materials, is the knowledge gained relative to the proper selection of material for a certain job.

That this is a great economic factor will be recognized at once. It is hardly probable that you would specify lead for your automobile piston, platinum for a log-chain, or mercury for a tea spoon. These would be glaring errors; yet, every day we see possibilities for improvement in every thing we use. The most easily obtainable material is not always the most economical to use, and if sufficient thought is not expended, it is easily possible, in the light of modern knowledge, to commit as serious an error as any of these mentioned.

Waste and inefficiency have been cartooned as demons scourging the sides of economy, and it is up to each one of us personally to constantly improve our products, methods and materials in the fight against such evils.

We must analyze in detail the problems confronting us with each and every new job. We must think of first costs of a given material, of its probable life, of its surroundings, and of its effects upon us. We must take past performance into consideration and we must visualize the future. And after weighing its possibilities in the balance of good judgment, we must use it to prove it.

In the field of water piping, there have been vast improvements in the past few years. We know that a water carrier should be tight; it should be combative to corrosion; it should be of sufficient strength to withstand all imposed strains; naturally it should not affect the water it carries so as to render it unhealthful, and last, but not least its cost must not be prohibitive.

[1] Presented before the Joint Meeting of Plant Management and Operation and Fire Protection Divisions, Buffalo Convention, June 9, 1926.

[2] President, Mueller Brass Company, Port Huron, Mich.

Costs of course are the essence of any economic program, and as these various other factors have such a decided bearing on total costs, they are of great significance and receive first consideration from every water works official.

The various condition which most affect the life of a service pipe material are as follows:

Corrosion
Galvanic action
Electrolytic action
Frost
Earth slips
Vibrations

Now the most widely used service is the galvanized iron pipe with a lead gooseneck. Probably next is the complete lead service, then there is lead lined iron pipe, cement lined iron, tin lined iron, wrought iron, yellow brass, Admiralty mixture, iron pipe size copper pipe, and the latest addition,—service pipe made from almost pure copper and with thinner gage walls than regular iron pipe size.

Each of these latter has been developed to meet the requirements imposed by some unusual condition which renders ordinary galvanized pipe short lived. All are successful in certain fields, but no one is successful in all fields. All are more expensive initially than galvanized iron pipe with a lead gooseneck, except the copper service pipe, with which it is about on a par for an average complete service of 30 feet.

Naturally, the first reason a water company replaces galvanized iron pipe with lead is on account of rust, and in some districts lead pipe is successful. On the other hand where lead must stand excessive pressure, water hammer, earth slips and vibrations, it must be made extra or double extra strong and this means that the invested capital of the city or water company is just that much greater.

Iron pipe size brass pipe (Muntz metal, 60 copper—40 zinc) has been used quite successfully, but where sea water or unusual soil conditions were present it became apparent that plain yellow brass was more or less of a failure. Admiralty pipe (70 copper—30 zinc) was then considered, and is now being extensively used in some localities. This in turn led to a red pipe (85 copper—15 zinc) which has rather recently been introduced as a commercial product, and for which it is claimed, that, because of the mixture proportions and

the arrangement or structure of its fibers, that it is more highly resistant to corrosion than are many other materials used.

Be that as it may, either Admiralty or the red pipe is very expensive on account of the difficulties attending their respective manufacture. And anyone of these three brass mixtures is liable to that bane of the brass manufacturers called "Season Cracking."

Because of the foregoing difficulties others branched off from brass pipe in another direction, that is, towards nearly pure copper. Copper has been the metal of the ages, and fabricated pieces have come down through centuries practically unimpaired. And so iron pipe size copper was tried in at least one community which installed thousands of feet of this material. Where corrosion was concerned it was the equal of, or better than, any of the service materials mentioned above and under practically all conditions; not because of its structure or any particular metallic combination, but because it was copper. To be sure, the iron pipe size cost more, but it would not rust in water, and it would withstand high pressures better than lead.

Now you will note that in these various developments, engineers were quick to see the possibilities of an alloy of copper, and as shown above, the trend of practice was towards pure copper, as represented by the changes from 60–40 mixture to 70–30 mixture to 85–15 mixture and then to iron pipe size copper. All of these however, are rigid pipes, thus necessitating the use of a gooseneck; and all require threaded joints. In turn threaded joints require a heavy wall pipe in order to get a reasonable amount of strength under the threads, which naturally is the weakest part of the pipe. Then in the particular case of copper pipe the threading is difficult on account of the softness and stringiness of the material, and there is that danger of the threads pulling out.

It was our idea then, to produce a non-threaded coupling whose metal mixture would be as near as possible to copper (but of sufficient strength to stand the imposed strains), and which would make an absolutely perfect joint. Such a coupling in combination with a relatively thin wall pipe made from 99.96 per cent copper (and such other ingredients as would give the greatest strength and ductility), would solve at once the several problems of threading, material costs, flexibility and ductility, and would still stand a pressure many times greater than would be required.

Therefore, the elimination of the gooseneck and the reducing of the

weight of the pipe by the use of the proper fitting solved the problem, and millions of feet of this material have been installed during the past two years all over the United States and Canada. It has been received with enthusiasm wherever it has been seen. It has all the good qualities of iron pipe size copper pipe, with the added advantage that a gooseneck is not required, and that it is in the same price class with galvanized iron pipe service.

We have avoided the scientific side of the discussion concerning corrosion, and we shall continue to do so. The multitude of theories extant, some of which are contradictory to others, is rather baffling. However we are not concerned particularly with what corrosion is or what causes it, but we are concerned with those materials which will resist it. And, again, we all look upon copper as the "metal for the ages" and in detail, as the most generally successful service pipe material.

Consistent tests, the results of which are in our records, show that copper will last longer in potable but slightly acidulous water than other materials. We believe that the passage of years will show the same to be true of soil which is similarly acidulous or alkaline. We are having the Bureau of Standards in connection with their country wide tests of material run such tests over a period of six years covering quite a variety of materials.

A most severe test given copper pipe for corrosion was the installation in an eastern city of several materials under a cinder ballasted track through which water was constantly trickling. Naturally no metal except the rare ones can exist under this treatment. But the copper service pipe was there when the rest were gone.

It might not come amiss, however, to quote an explanation of corrosion which is incorporated in Appendix B of the "Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings" (July 3, 1923), Bureau of Standards. Page 213 contains a table entitled the "Potential Series of Metals," which is partially as follows:

1. Zinc
2. Iron
3. Nickel
4. Tin
5. Lead
6. Copper
7. Mercury
8. Silver

and to quote the report—"the higher the potential," (meaning the higher the position in the scale), "the higher the solution pressure of the metal, and in general, the greater the chemical activity." Please note that zinc is at the head of the list, while copper is near the end.

Regarding the metals in nature we are struck with how nearly they adhere to this "potential series" in the various natural reactions. The precious metals, gold, silver, etc., and the semi-precious copper are frequently found in their pure state, the baser metals practically always found as a salt or an oxide, they lack stability.

Generally speaking, galvanic or battery action makes itself felt when two associated but dissimilar metals are in the presence of an electrolyte. In detail we are apt to find that a brass pipe with a lead gooseneck in a slightly acidulous soil is peculiarly susceptible to galvanic action. Also we find that in Muntz metal (60 copper—40 zinc) the same condition exists, as is proven in condenser tubes where the zinc becomes dissolved, leaving a porous mass of copper.

The practise of inserting a bronze corporation stop in a cast iron main, and attaching thereto a lead gooseneck to which is connected a galvanized iron pipe and in turn a bronze curb stop has interesting possibilities under certain soil conditions. The use of copper service pipe with fittings of high copper content approaches the goal of perfection generally where corrosion is troublesome.

Naturally this holds true for electrolytic action. We learn that this comes from stray or ground currents, from power lines, power house, and even from telephone circuits. The current seems to run along a service pipe until it comes to a "hopping off" place, and, if soil conditions are just right and the current pressure and density are just right, it carries off some of the service pipe material with it, for it is a true electroplating (off) action.

Although it is possible to take some acidulous earth for an electrolyte, a piece of pipe for a cathode, and another piece of pipe for an anode, and plate from the one to the other by impressing a small current of electricity, it is not always possible to predict the effects of certain combinations of stray ground currents with certain soils, adjacent water carriers, and ore or rock bodies.

The safe thing to do is to use a material from the curb to the main, which will have sufficient carrying capacity so that for most cases at least, the current will not be induced to jump off. Copper service pipe seems to fit this requirement. For there is enough cross sectional area so that, when the high electrical conductivity is taken into

consideration, it will afford the path of least resistance to the ground at the water main.

The instance has been known where various service materials were replaced once a year due to electrolytic action from single trolley street railway stray currents. Copper might not absolutely cure a particular case, but it will most certainly help it to a great extent.

Getting away from the realm of chemistry let us check up the various materials for frost action. Iron pipe of various types is easily disposed of. It will not do. It opens up in the weld.

Lead pipe undergoes a physical change with characteristic loss of strength due to being stressed so far beyond its elastic limit. It sometimes opens along the side, particularly on the second or third freeze. We have taken various materials and subjected them to from three to twelve hour freeze test in a cold room, a constant temperature of ten degrees below zero being maintained, our method being to plug one end of a sample and put a pet cock in the plug in the other end, so that we could be sure there was no air present to act as a cushion.

Iron pipe is never good for even one complete freeze under these conditions. Lead pipe for as high as three, if it is double extra strong. Brass pipe is satisfactory except that in some cases it has a tendency to burst fittings, strip threads, etc. Copper service pipe seems to be in a peculiar balance. The freezing overcomes its elasticity, but does not move the fibers in such a way as to weaken them. This is shown by the fact that continued freezes on the same samples produce slightly less percentage expansion each time.

We have a sample of copper service pipe which was frozen solid eleven successive times; being thawed out with a torch between freezes and refilled with water to make up for the expansion; and it does not show a sign of fracture.

The question of thawing copper pipe with electricity has been raised. Our experiences show that the same outfit as used on other services in Port Huron, Michigan, by the Detroit Edison Company, will thaw a copper service satisfactorily, although due to the low resistance of the copper, it is a somewhat longer operation than with galvanized iron pipe. This, however, is only a question of transformer capacity and any electrical company can cope with the situation.

It is noteworthy that water works officials who have used copper service pipe say that it is the salvation for those northern districts which experience so much trouble each winter.

One of the first experiments which was performed on copper service pipe was to determine its flexibility and ductility. Many of you gentlemen have seen at conventions the test frame which was loaded down 30 inches from horizontal, till, at the low point, it was within 2 inches of the floor without a sign of a leak, and supporting, in some cases, more than 2000 pounds of *live* weight.

We have tried many experiments along this line, many of them under more practical conditions. We challenge you to produce a service material or combination of materials which will stand more abuse, more load, than will copper service pipe.

You have all seen rigid pipes break, goosenecks kink and pull apart, you have observed costs pile up when a rock or stump must be cleared from the grade; and you have heard the wails of home owners whose lawns and sidewalks have been torn up to find that a lead pipe had sheared over the edge of some unremoved sheeting over which the service had been laid.

We are all acquainted with what happens in mining districts when the earth's crust makes a sudden shift and we can picture the bills rolling in for scores of new water service, because lead is not ductile enough to take care of other than the slightest earth movements.

Vibrations due to street cars, loaded motor trucks and earth tremors, all contribute towards shortening the life of service pipe. Failure, if from this cause alone, usually manifests itself at the joints, but usually these things are contributing factors. When a pipe is under stress from any cause, the constant motion of vibration, although of small magnitude, materially helps to shorten the time before ultimate failure.

Again copper service pipe triumphs. The joints are so much superior to screwed joints that it is practically impossible to endanger them. We have tried out service installations with this joint (while the pipe was weighted with one ton of cement) by attaching a heavy air vibrator whose power is many times that coming from the usual sources as mentioned above, as well as many other tests devised by our engineers, which have only proved the good qualities of a joint which for its effect depends on the compression around the entire surface of the pipe (inside and out) of a pair of opposed convex surfaces which embed themselves and make a joint as strong as the pipe itself.

Copper pipe is in the same price class with the average galvanized iron and lead gooseneck service. Actual comparison on a job in one

instance shows it to be only a few cents over either galvanized or wrought iron with gooseneck and from \$1.50 to \$3.50 cheaper than other materials such as brass pipe or double extra strong lead pipe. These figures are for a complete 20-foot service.

Still another feature of the economy of copper service pipe is that of installation. We have many letters in our files regarding this. They speak of the light weight and the ability of a man or a truck to carry a larger supply of services to the job; the small number and the convenience of the required tools; the ability to lay the pipe around an obstruction; the ease with which a hole is forced through clay under a sidewalk and above all the great saving in time for the completed service which results in a big increase in daily production.

NEW FEATURES OF WATER PURIFICATION PRACTICE IN OHIO[1]

By F. H. Waring[2]

The employment of water purification devices in a special way in water purification practice in Ohio will be discussed from two general standpoints. (1) A description of the research studies and experiences of several water purification and softening plants, and (2) a discussion of details and tendencies in the use of certain new water purification devices.

Pre-chlorination. Treatment of raw waters with chlorine is not a new procedure. There are, however, some new phases of this treatment that are being experimented with in Ohio. Studies are now being conducted at the Akron plant in the attempt to eliminate a troublesome gas-forming organism that survives the usual filtration and chlorination treatment. The first part of the research involves the application of liquid chlorine in limited amount into the raw water conduit at the impounding dam about one-half mile from the filtration plant. The chlorine applied will be limited to an amount such that no residual chlorine is present in the water entering the mixing chambers. The second phase of the research involves application of heavy amounts of chlorine at the initial point, followed by de-chlorination using sulphur dioxide at the mixing chambers. Results of these studies will not be available entirely until about October of this year.

Another research with chlorine application to raw water has been under way for almost a year, the work being started at Ironton and continued at Sandusky. The purpose of chlorine application in these instances is to relieve the extremely high bacterial load upon the ordinary purification processes. The chlorine application experiments are being conducted in two ways in similar manner as that described in the Akron case; first, a mild treatment leaving no

[1] Presented before the Water Purification Division, Buffalo Convention, June 9, 1926.

[2] Chief Engineer, State Department of Health, Columbus, Ohio.

residual chlorine in the water passing to the coagulation basins; and second, heavy chlorination followed by de-chlorination before the water is coagulated. Ironton has a yearly average B. coli content of about 16,000 per 100 cc. with daily peaks as high as 100,000. Sandusky has considerably less pollution load, the yearly average being about 1500 B. coli per 100 cc. with daily peaks of 10,000. The Ironton experiment has proved a failure on account of the presence of industrial wastes containing phenol in the Ohio River water, giving rise to chloro-phenol tastes that made the use of chlorine impossible in the water treatment; hence the activities have been transferred to Sandusky, where no phenol wastes are expected to interfere. From the bacterial standpoint the Ironton experience indicates that chlorine may be utilized to relieve the heavy pollution load and not interfere with subsequent processes, if no residual chlorine is left in the water coming to the coagulation basins.

Adjustment of pH Value for Optimum Coagulation. The operators in this state have studied the raw water conditions with a view to determining the optimum pH value for coagulation. Generally speaking not a great deal of difference seems to prevail in Ohio waters between the raw water pH value and its optimum for coagulation. However, two or three of the plants dealing with impounded reservoir or lake waters have felt that it was promising to have research along lines of reducing the pH value in the raw water before coagulating. E. E. Smith, superintendent of filtration at the Lima plant, has had in service for approximately one year devices to apply carbon dioxide gas to the raw water as it enters the filtration plant and prior to application of the coagulant. The treatment was begun as an experiment and has been so successful that the equipment first installed has been kept in regular use, and the city is now taking steps to provide permanent and more efficient equipment. The yearly average pH value of the raw water is about 8.0. The average optimum pH value for coagulation is found to be about 7.0. The carbon dioxide applied reduces the pH value about 0.3 and accomplishes a reduction in coagulant required of about 0.5 grain per gallon. The treatment has been limited to the above extent by reason of the undesirability of increasing the free carbon dioxide content of the filtered water, in order not to produce a condition of corrosive water. The plant is not adapted conveniently either for pumping the filtered water to aeration devices, or for secondary treatment with lime to correct the corrosive tendency of

the final effluent; however, it is expected at a later date that this feature will be remedied in order that even greater savings may be obtained in coagulant application by first employing carbon dioxide gas to bring about the reduction in pH value of the raw water.

Double Coagulation. The term double coagulation has been applied to the use of two series operated coagulation basins with separate mixing chambers or devices to bring about coagulation in each basin. At the present time two Ohio filter plants have been rearranged to accomplish double coagulation (Portsmouth and Cincinnati); two plants were constructed new including this feature (Ironton and Toronto), and one plant is under construction utilizing series operated coagulation units (Norwalk).

There are two primary reasons for the tendency to use double coagulation in Ohio. (1) Ohio River carries a load of bacterial pollution that is too heavy for ordinary water purification processes employing one stage of coagulation; that is, the final effluent is made safe only because a great burden of purification rests upon the final process of chlorination. During the past two or three years industrial wastes containing phenol have seriously interfered with the use of chlorination for Ohio River water and hence it has become necessary to resort to other means, at least for considerable intervals of time. An excellent discussion of Ohio River conditions in relation to limitations of water purification processes was presented by H. W. Streeter to the fourth annual meeting of the Ohio Conference on Water Purification. (2) A few reservoir waters in this state contain considerable amounts of color and have relatively low alkalinity. Double coagulation devices furnish excellent opportunity for coagulation of the color under these conditions, since any desired amount of alum may be applied alone in the first basin; lime may then be applied in the secondary basin to precipitate any free aluminum and to neutralize the corrosive condition of the water. The foregoing practice while new in this state has been copied from the experiences of the Wilmington, N. C. plant as reported by Catlett and Norcom.

Excess Lime Treatment. The term excess lime treatment has been given to the water treatment practice which includes the application of enough lime to the raw water to create a caustic alkalinity. Such is the practice at water softening installations for the purpose of bringing about the water softening reactions.

It was observed by C. P. Hoover, soon after the Columbus plant was placed in service, that the causticity thus obtained created a

condition unfavorable to bacterial life, and that the effluent from the settling basins was sterile. At his suggestion Youngstown instituted the excess lime treatment for the badly polluted Mahoning River water used as a source of supply at that plant. That the treatment has been a success is demonstrated by the experience of the last few years. The raw water pollution load at Youngstown is probably the greatest of any water treatment plant in the country. The yearly average B. coli index exceeds 20,000 per 100 cc. and it is not possible to use chlorine at this plant because of interference by phenol bearing wastes. The final effluent during the past year has not shown a single positive presumptive B. coli test in any of the five 10 cc. portions tested daily. The safety of the water is entirely dependent therefore upon careful application of lime to the river water, and W. I. Van Arnum, superintendent of the Youngstown plant, deserves great credit for the careful conduct of this lime treatment.

Combination of Excess Lime, Double Coagulation, and Adjustment of Raw Water pH Value. Following the unsuccessful attempt at Ironton to relieve the bacterial load in Ohio River at that point, a change of treatment was made beginning in December 1925. The experience of Youngstown and Lima has been made use of at Ironton in the following schedule: The plant has double coagulation facilities; accordingly, lime was applied to the primary basin in an amount to produce causticity, therefore sterilizing the supply. Alum was applied at the secondary basin to coagulate the turbid Ohio River water. It was noted that considerable alum was required if the influent water to the filters was to be kept in a condition to prevent carbonate scale forming on the sand grains as a result of the excess lime used. In order to economize on the alum, the pH value of the water is being reduced by the use of carbon dioxide gas applied at the mixing chamber of the secondary basin. A saving of more than two grains of alum per gallon seems to be promised and the water coming to the filters contains no mono-carbonate alkalinity that would encrust filters or piping beyond the plant. By means of the practice above related, it will be possible to produce excellent filtered water without the use of any chlorine; without increasing the cost of the water treatment over previous practice; and having as reserve processes, or factors of safety in the treatment, both the coagulation in the secondary basin and the rapid sand filtration.

Lime-Soda Softening Process for Small Municipalities. Experience

in the industrial field has been copied and applied in convenient manner at two small municipal softening works in this state, where the fill-and-draw system of water softening is used. The settling basin also constitutes the mixing tank, the mixing being accomplished in one instance (Glendale) by mechanically operated agitators and in the second instance (Batavia) by compressed air. The charge of chemicals is applied while the tank is filling with water. Fundamental principles of water softening are taken advantage of, in that mass reaction of the chemicals with the water is obtained; efficient mixing by mechanically operated agitators takes place; and a perfectly quiescent settling condition prevails, because the tank is allowed to remain idle before water is drawn off to the filters from the surface by a floating outtake. It has been our experience that the fill-and-draw system of softening by the lime-soda process is better adapted for the very small plant than the continuous flow system.

Municipal Zeolite Softeners. The employment of the zeolite process for municipal water softening is of fairly recent occurrence in this state. One plant is under construction for a small community, and two others are proposed for immediate installation. Advantages of this process over the lime-soda process are pronounced in the case of the small community which already has an adequate supply of well water of good sanitary quality. Some of these advantages are the following: By operation of convenient by-passes any degree of hardness desired may be permitted in the final product; the installations are compact; they are considerably cheaper to install; operation costs are about the same; and very little supervision is required.

Natural Recarbonation. Oberlin has the oldest municipal water softening installation in the country utilizing the lime-soda process. Incrustation and depositing of carbonate of lime have occurred extensively in the distributing system. The excelsior filters originally provided were abandoned last year when Oberlin began the practice of natural recarbonation, which was made possible by the use of an existing large open reservoir for the storage of the treated water. Chlorine is applied to the final product delivered to the system as a factor of safety on account of the open storage of the treated water. The results have indicated that enough carbon dioxide is absorbed from the atmosphere in the thirty days or more of storage to furnish a stability of softening reactions. Although

all of the normal carbonates are not converted by this atmospheric absorption it appears that the depositing portion of these carbonates is eliminated. It is too soon to state if the open storage of such water will not invite other difficulties such as algal growth.

Iron Removal and Softening. Ohio has about 15 iron removal plants in which ground water is treated. The original devices used were aeration, sedimentation and rapid sand filtration. The fundamental principles involved in iron removal practice, as regards Ohio conditions, have been well stated by A. E. Kimberly in his paper published in the Second Annual Report of the Ohio Conference on Water Purification, as follows: (1) The water must be thoroughly oxidized to precipitate the iron (2) Some of the precipitated iron is colloidal in character, but may be coagulated by catalytic action in contact with previously precipitated iron sludge. In the newer types of plants, therefore, sedimentation is being abandoned in favor of contact filters.

At one recently completed plant (Newton Falls) the devices are placed one above the other, on what might be called the "skyscraper" plan. The water from the wells is pumped to nozzle aerators located at the top of the structure, which spray directly upon the contact filters, from which the water flows to the sand filters at the first floor level; the effluent from the sand filters is collected in the clear well substructure.

At another plant it is proposed to substitute for the silica sand in the rapid sand filters zeolite sand, in order that the water may be softened in addition to the iron removal. The experience of the past year would seem to show that contact filters are very efficient in bringing the iron out of solution and in removing the greater portion of the iron. Therefore, the use of the zeolite in place of the filter sand should result in satisfactory softening without the zeolite being interfered with by iron depositing around the zeolite particles.

There is a general trend toward municipal water softening in all new development of water treatment in Ohio. It seems that our people are requesting a soft product as well as a pure product and this requirement appears to be independent of whether the water supply is of surface origin or of ground water origin.

DISCUSSION OF NEW WATER PURIFICATION DEVICES

Coagulant Feed Devices. Up until a few years ago coagulant was applied at practically all plants by means of solution feed tanks and

orifice devices. With one or two exceptions all of the last 10 or 12 plants constructed in this state have utilized dry feed apparatus for applying the chemicals. Reluctance in changing from the solution feed to the dry feed system was observed at first due to mechanical difficulties encountered in the earliest types of machines; these difficulties have been largely eradicated.

For application of the coagulants it was common practice five or ten years ago to provide metal piping of special character, these pipes being imbedded in the concrete of the filter plant structure. Clogging troubles have demonstrated that it is advisable to place piping in accessible locations, and provide for short travel of the chemical from the machine to the point of application. At all of the recently constructed plants flexible hose of rubber or composition material has been employed, and experience indicates that clogging troubles are now practically nil. These hose pipes are placed in the open and the most direct route from the chemical machine to the water receiving the chemical is taken.

Mixing Devices. Early design employed gravity baffled mixing chambers with either horizontal or vertical flow of the water and long periods of retention, many of the plants having as much as one hour in the mixing chamber. None of the new plants installed in the last two or three years in Ohio use this type of mixing. One style of gravity mix, however, is now employed, namely, the hydraulic jump. The new Baldwin filtration plant at Cleveland used this device which was developed by J. W. Ellms, engineer in charge of water purification at Cleveland. This style of mixing chamber utilizes velocity head for a very efficient mingling of the chemicals with the water. With the exception of the Cleveland plant all other new plants in this state are utilizing some variety of a mechanical mixing chamber. The incentive for this style was largely the experimental work done in connection with the design of the Sacramento filtration plant and corroborated by laboratory experiments of C. P. Hoover and others in this state. Two general types are used. The vertical hanging blades or agitators, and the horizontal suspended blades. Generally two tanks are provided to give flexibility, each with individually operated single shaft agitators. At first more than one agitator shaft was employed in a tank, but experience indicates that undesirable velocities are set up which break the floc formed.

The tendency to use the mechanical mix is accounted for by some

of the advantages obtained, as follows: The system does not utilize extra head through the device; ease of construction makes it possible to enclose the entire mixing chambers within the chemical house; likewise chemical feed equipment may be placed immediately adjacent, with direct application of the chemicals through short lines; in most instances less than two horse power is required for operating each agitator; a definite velocity may be obtained irrespective of the changes in flow of raw water through the plant; and the velocity may be adjusted at will by varying the speed of the motor driven mechanism. Generally speaking, these tanks are designed to hold about 20 minutes retention and the speed of the agitator is set to give the water a velocity of about one foot per second.

Clarifiers. Municipal water treatment practice has copied from industry another device, the clarifier, which has been developed largely by the Dorr Company. There are three in service in Ohio, all three of them in connection with water softening installations. The character and volume of the precipitate resulting from the raw water treatment determines to a large extent the advisability of installing thickening devices of this nature. For the most part turbidities are not encountered in Ohio that would warrant the installation of clarifiers in ordinary water treatment practice. The three softening plants employing Dorr clarifiers are Newark, Greenville and Piqua. The first installation was circular in style, but the two recent ones are square. The water is retained about one hour and permitted to flow through the clarifier at a low velocity of travel somewhat less than one-half foot per minute. The mechanically operated thickener is set for a slow rate of travel usually about 4 revolutions per hour.

The advantages of the clarifier particularly for water softening practice are seen from the results cited for the Newark plant. The clarifier removes about 98 per cent of the total suspended matter present in the water leaving the mixing chambers. Another advantage is that sludge removal may be conducted continuously and in less objectionable manner. This item is of particular importance where a small stream must receive the discharge of the sludge and waste water from the purification works. A striking inference may be drawn from the performance of the clarifier in the softening practice, namely, the great reduction in size of settling basins needed prior to filtration.

At the Newark plant installed two years ago regular practice was

followed and settling basins holding 8 hours of supply were constructed. Based upon the performance of this plant the Greenville and Piqua designs have reduced the settling basins capacity to retentions of from two to three hours. In the latter design a by-pass of the settling basins has been arranged in order to determine whether or not all of the settling basin may be omitted.

Carbon Dioxide Application Equipment. Carbon dioxide gas is employed in water treatment at several plants in this state; for the most part this treatment is used at softening plants for the prevention of after-precipitation of mono-carbonates. There are two general features of carbon dioxide application; the generation equipment and the absorption chambers.

Research work is still going on with regard to the best method of generating carbon dioxide for water treatment practice. In Ohio four plants are using coke for fuel, one uses oil, one uses powdered coal, and one contemplated will use producer gas. Based upon the experiences thus far it would seem that burning of coke affords the best way of obtaining carbon dioxide for the medium size and small plants. For very large installations it appears now that the burning of producer gas will be the best. It is this type of installation that the City of Columbus is going forward with. The producer gas will be manufactured first by burning coke with a restricted air supply for draft and the resultant gas then burned under the boilers, in order to utilize the heat of burning of the producer gas. The chimney gases from this boiler will then carry a very high percentage of carbon dioxide and be quite serviceable for carbonating the large volumes of water at this plant. It seems desirable to include with the generating equipment a scrubber and drier to take out impurities from the gas that might affect the compressor. Experience at two plants has shown that the compressor is affected if insufficient scrubbing of the gas is done before compressing. However, one new plant (Girard) is employing a new type of compressor that is water lubricated, which promises to make possible the omission of scrubber and drier as a preliminary to compressing the gas.

At the first plant to install carbon dioxide equipment (Defiance) special provisions were made to cause the gas to be absorbed by the water. A carbonation chamber was arranged that had filtros diffusers to break up the gas in small bubbles; also baffled compartments to cause the water to travel downward against the upward flow of bubbles; and drainage facilities to take away possible pre-

cipitates that might be formed. Experience has shown that the precautions cited are not needed to obtain satisfactory carbonation. The recent plants are employing the last portion of the settling basin, say a capacity of thirty minutes retention, instead of providing separate basins. No particular baffling is done except to partition off this compartment from the remainder of the basin and thus prevent the disturbing of suspended matter already settled out in the basins. For distributing the gas ordinary grids of piping with small perforations, say from $\frac{1}{16}$ to $\frac{1}{8}$ inch, are giving good satisfaction. Tests with such piping show that over 90 per cent of the carbon dioxide applied is absorbed even when the depth of the water is not greater than 8 or 10 feet.

CONCLUSION

In conclusion the writer wishes to state that the material presented in this paper is drawn largely from the work of the Ohio Conference on Water Purification and credit for new thoughts gleaned belong to the men in charge of the particular plants cited. This Conference comprises the men actively in charge of the water treatment plants. They have met with the State Department of Health annually for the past five years, and the conference has thus become the medium of exchange of ideas, experiences, and the results of research studies.

THE THIN PLATE ORIFICE FOR THE MEASUREMENT OF WATER[1]

By G. D. Conlee[2]

Every one interested in water works engineering is familiar with the use of the venturi tube for the measurement of water flowing in pipes. The venturi tube has been a commercial article for nearly 40 years, and during that time it has become the standard method for the measurement of cold water. The constants have been established and the limitations are known, so that a venturi tube can now be installed with the expectation of satisfactory results.

Developments in other fields of engineering have led to the adoption of the thin plate orifice for the measurement of fluids, which includes steam and gases. You doubtless know of the use of orifice flow meters for the measurement of steam. I want to take this opportunity of bringing to your attention the advantages in the use of this type of meter for the measurement of water.

Some years ago the American Society of Mechanical Engineers appointed a Special Research Committee on Fluid Meters. Part of the members were interested in the manufacture of meters; one representative being chosen from each company in the field at that time. The remainder were men, who in the practice of their profession had had extensive experience with flow meters of various kinds. The Committee spent a great deal of time and effort, and in 1924 made a report covering part one of the subject. This report deals only with the primary element of the fluid meter, which can best be described by quoting from their introduction as follows:

> All Fluid Meters consist of two distinct parts, each of which has a different function to perform. The first is the primary element, which is in contact with the fluid, and is acted on directly by it. The second is the element which translates the action of the fluid on the primary elements into volume, weight or rates of flow, and indicates or records the results.

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[1] Presented before the Manufacturers' Association meeting, Buffalo Convention, June 8, 1926.

[2] Republic Flow Meters Company, Chicago, Illinois.

Similarly the present paper deals with the primary element as defined above. It is based upon this report and all of the values for factors given are taken therefrom.

The venturi tube, the flow nozzle, and the orifice, as well as the other differential mediums used with the various flow meters now on the market, have common characteristics in that the flow through the primary element produces a pressure difference which the secondary element translates into rate of flow. This difference is between the static pressure at two different sections of the stream.

If a small hole is drilled perpendicularly through the wall of smooth pipes along which fluid is moving, the inside edge of the hole free from burr, and the hole is connected to a pressure gauge, the observed pressure is called the "Static Pressure" of the fluid that is moving past the hole.

EQUATIONS

The theoretical equation of the head meter, that is the venturi tube flow nozzle or thin plate orifice is:

$$V_t = A_1 \frac{1}{\sqrt{R^4 - 1}} \sqrt{2\,gh}$$

where V_t = theoretical rate of discharge, cubic feet per second.

A_1 = area of the entrance section at the up stream pressure connection, square feet.

R = ratio of entrance to throat diameter D_1/D_2

g = acceleration of gravity, 32.174

h = difference of level (feet) at which the liquid stands in two vertical tubes which are connected to the side holes at entrance and throat respectively, and are either open at the top or connected through a closed air space.

The factor $\frac{1}{\sqrt{R^4 - 1}}$ depends only on the diameter ratio and is independent of the absolute size of venturi, nozzle or orifice.

The factor A_1 is fixed only by its absolute size. These two factors may be combined into a single constant,

$$M = \frac{A_1}{\sqrt{R^4 - 1}}$$

which can be computed once for all for any installation and the equation becomes

$$V_t = M \sqrt{2\,gh}$$

For various reasons, which will not be discussed here, the rate of

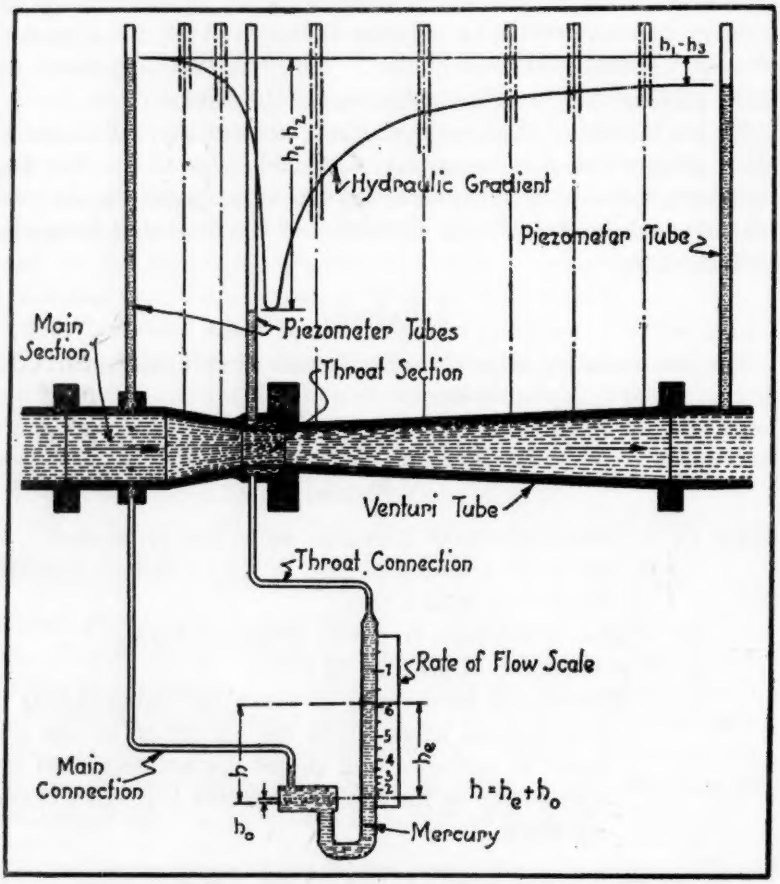

FIG. 1. TYPICAL SECTION OF VENTURI TUBE

flow V (cubic feet per second) observed is usually different from the theoretical value, and the practical equation is

$$V = C\,M \sqrt{2\,gh}$$

in which C is the discharge coefficient.

VENTURI TUBE

The principle upon which the venturi tube is based was first announced in 1797, in the published researches of J. B. Venturi, an Italian philosopher. He observed that fluid discharged through an expanding nozzle exerted a sucking action at the smaller diameter which diminished as the diameter increased towards the outlet. It is apparent that he considered this phenomenon scientifically interesting, but without practical value.

In 1887 Clemens Herschel conducted a series of hydraulic experiments on various sizes of tubes composed of two conical portions joined at the small ends, thus forming a contraction near the middle. As a result of these experiments, the design of tubes now in common use was established and as the final outcome of the experiments a patent was granted to Mr. Herschel on the device which he named a venturi tube.

Figure 1 is a section of a typical venturi tube, the proportions much the same as those originally adopted by Mr. Herschel. Beginning at the up stream end, it consists of a short cylindrical portion, machined to a definite diameter and containing the side holes for measuring the up stream pressure. Then comes the entrance cone which reduces the diameter to that of the throat which is accurately machined and has side holes for taking off the throat pressure. The end of the throat leads into the exit cone or diffuser, which increases the diameter to that of the pipe line.

If the venturi tube is well made and properly installed, the value of C is between 0.97 and 1.00 with the mean value of 0.985 generally used.

THIN PLATE ORIFICE

The thin plate or sharp edged orifice was used for many years to measure rates of discharge from tanks into the open air. It was also known that an orifice in a straight run of pipe could be used for the measurement of water, provided the orifice was calibrated in place; that is, it was an accepted fact that an orifice would produce the same differential pressure for the same rate of flow at all times. It was not until about fifteen years ago that any one conceived the idea that an orifice could be designed to meet definite conditions and could be used for measurement of water in exactly the same manner as a venturi tube. A number of independent investigations were started and a respectable volume of data has been collected.

Since that time various tests of orifices have been made under all sorts of conditions, and the accuracy of the data and the consistency of performance has been established. When the same care is taken with the installation of an orifice as with a venturi tube, the same accuracy of results can be guaranteed.

Figure 2 is a diagram illustrating the installation of an orifice in a pipe. In its simplest and most familiar form, the orifice is merely a round hole in a thin flat diaphragm clamped between the flanges at a joint in the pipe line, with the hole concentric with the pipe. In practice the orifice is usually made from sheet monel metal from $\frac{1}{32}$ to $\frac{1}{16}$ inch in thickness. At times a thicker plate is used and the plate is then chamfered around the hole on the down stream side so as

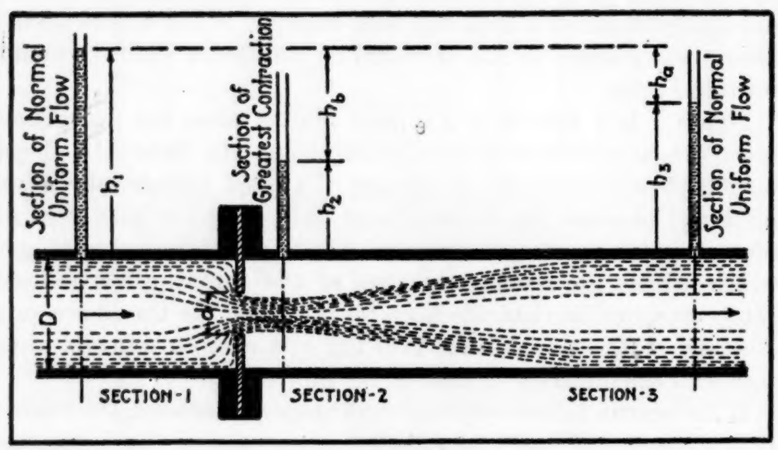

FIG. 2. THIN PLATE ORIFICE IN PIPE

to leave only a thin edge, while the up stream face of the plate remains flat, with a sharp 90 degree corner at the edge of the hole.

The dotted lines are the so called "lines of flow;" that is, the supposed path of particles approaching, passing through and leaving the orifice. The vertical, open ended pipes shown indicate the pressure at the three points.

1. Up stream before the flow has been affected by the orifice.
2. At the point of minimum pressure below the orifice known as the vena contracta.
3. At point of restoration, which is about four pipe diameters below the orifice.

These three points correspond to the three pressures considered on a venturi tube.

It is a familiar observation that a free jet of water from a sharp-edged orifice is not cylindrical, but contracts at first. On account of the flow inward toward the orifice on the up stream face of the diaphragm, the outer filaments of the jet as it leaves the orifice have a component of velocity toward the axis, so that the profile of the jet is concave and decreases in width. At a certain distance from the plane of the orifice, the jet has a minimum section, or vena contracta, where the area is constant for a short distance. The highest speed and lowest static pressure are not reached in the plane of the orifice, but at the vena contracta, which corresponds to the end of a flow nozzle discharging a jet of water into the open air. The jet from a thin plate orifice inserted in a pipe line acts in a similar manner. This is shown by the dotted lines of flow in figure 2.

If the orifice is small compared with the pipe diameter, the result is merely a jet from one large space to another. As the orifice diameter is increased to a larger and larger fraction of the pipe diameter, the vena contracta moves closer to the plane of the orifice and the jet is surrounded by a dead space filled with eddying water. The jet is thus retarded and it must expand in cross section so that after a few pipe diameters it fills the whole section of the pipe. It has not been proved definitely that the pressure in a side hole must be the same as it is in the jet at the same distance from the plane of the orifice. However, it has been shown by visual tests in glass tubes that the vena contracta is in the same plane as the side hole showing the lowest pressure. Therefore, this pressure may be considered the same as the static pressure in the vena contracta.

If the diameter of the vena contracta could be measured directly, the discharge coefficient in the equation given previously would be nearly unity because the speed actually attained in the vena contracta is closer to the theoretical value than is the throat speed of the venturi tube. Since the diameter of the vena contracta cannot be measured directly, the diameter of the orifice is used and this accounts for the coefficient being from 0.60 to 0.62, depending upon the size of pipe and the orifice ratio.

ORIFICE INSTALLATION

It is usually possible to select a flange in the line where an orifice can be installed without any change in piping. Twelve diameters

of straight pipe on the high pressure side of the orifice is ample to insure satisfactory results under any conditions of flow. In practice this length of straight pipe is not always available. The length actually necessary for satisfactory results depends upon the ratio of the orifice diameter to the pipe diameter and also the velocity of the flowing fluid.

The orifice is inserted in the pipe between gaskets. It is made of a proper size to fit inside of the bolt circle and has pins on the handles to center the opening in the pipe. The two pressure taps are made one on each side of the orifice. A $\frac{3}{8}$-inch pipe connection is all that is required and it can be tapped directly into the wall of the pipe. Care must be used that the nipple does not project into the pipe on the up stream side of the orifice because an aspirating effect may be produced that will affect the accuracy of the meter results.

In case of bell and spigot pipe, the orifice is put in at the bottom of the bell and held in place by the spigot. When the joint is made the orifice is solidly held and it is only necessary to make the pressure connections on either side of the orifice.

The orifice is comparatively inexpensive. Consequently it can be designed for present needs. Should increased demand occur, it is a simple matter to install a new orifice of increased capacity. This is one very important advantage of the orifice. When distributing systems are laid out there is always a liberal allowance made for future growth. Consequently if the meter is designed for the ultimate capacity, it will be operated for a number of years below half capacity, and the accuracy may be in question during low flow periods. Initial readings are very important because they serve as a starting point for checking future growth and it is well worth the small additional expense to have meters which at all times will read within the most accurate range.

The ease of installation and small interruption of service make it possible to install district meters in lines already in service. When bell and spigot pipe is used, it is possible to install an orifice using ordinary fittings without the delay caused by waiting for special flanged pipe.

It is customary to guarantee an accuracy within ± 2 per cent for flow meters when properly installed. This guarantee is based upon the installation of the orifice in commercial pipe. If the pipe section on the high pressure side of the orifice is machined to exact size for two pipe diameters, a guarantee of accuracy within ± 1.5 per cent can be made.

The orifice is made from monel metal and the pressure drop through the orifice is so low that there is no cutting of the edge to enlarge the orifice size. Neither is there any deposit of sediment on the edges of the orifice that will reduce the size of the opening. In practice the orifice remains clean and the accuracy is maintained. There are orifices that have been in service for ten years, and the accuracy is the same as when first installed.

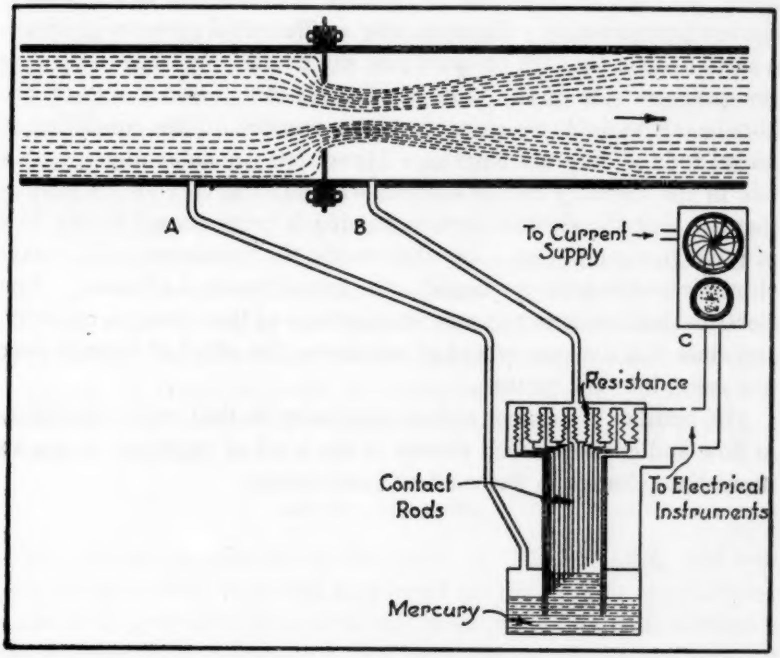

FIG. 3. ELECTRICAL MEASUREMENT OF FLOW

Let us sum up the advantages resulting from the use of the orifice for the measurement of water.

1. Low first cost.
2. Ease and economy of installation, as it may be placed in an existing flange in the pipe.
3. Accuracy to compare with other types of differential medium.
4. Maintained accuracy.

APPLICATION

So far the discussion has dealt simply with the use of the thin plate orifice for the measurement of water. Now we will consider a few applications of this type of differential medium.

Figure 3 illustrates the principle of electrical operation. The simplicity of the method for measuring the flow of water in pipes is readily apparent. As shown in this cut, the standard thin plate orifice is installed in a pipe and connections are led from the two points "A" and "B" to the meter body. The difference in pressure between "A" and "B;" that is the differential pressure, is balanced by mercury in a U-tube. The two legs of the U-tube have different areas; the high pressure side being large in proportion to the area of the low pressure side. Consequently a differential pressure produces a small drop in the high pressure side and a relatively large rise in the low pressure side of the U-tube. In this low pressure side of the U-tube is a variable resistance having a number of taps consisting of nickel rods of different lengths. These rods are so arranged that a rise in the mercury makes contact with successive rods in such a manner that the electric current flowing is proportional to the flow of water in the pipe line. In other words, the resistance in the meter circuit is inversely proportional to the flow of water at all times. The electrical instruments measure the rsistance of this circuit accurately, and since it is a measurement of resistance, the effect of voltage does not come into the picture.

The number of contact rods is very large so that every variation in flow and corresponding change in the level of mercury causes an immediate change in the reading instruments.

EIGHTEEN MONTHS OPERATION OF THE DETROIT FILTRATION PLANT[1]

By William M. Wallace[2]

The Detroit filtration plant was formally opened and placed in service on December 21, 1923.

The general interest manifested in the operation of the Detroit plant warrants the belief that a brief history of "observations made and experiences resulting from the two years of its service" will be appreciated by the members of this convention.

It is recognized that the Detroit filtration plant has a greater filtering capacity than any other plant in the world, having a daily filtering capacity of from 320 to 360 million gallons.

In the construction of the Detroit filtration plant there were no unusual departures from the general design of other plants, exclusive of the mixing chamber which is considerably smaller in proportion to the capacity of the plant than those which have been provided in most recent filter installations.

MIXING CHAMBER

The mixing chamber is 18 feet wide by 240 feet long, and was designed to provide thorough and rapid mixing at high velocities by means of a diversified system of alternate sets of vertical and horizontal baffle walls, so arranged that, operating at maximum capacity, the velocity through the chamber is approximately 90 feet per minute, and the mixing period slightly less than 3 minutes.

Provision was made for introducing the coagulant, sulphate of alumina, at the initial point of the chamber.

During the first six months of operation close observations were made of the applied water, at the outlet end of the mixing chamber.

Coincident with similar conditions in other plants it was noticed that at indefinite periods there was a decided change in the appear-

[1] Presented before the Water Purification Division, Buffalo Convention, June 10, 1926.

[2] Board of Water Commissioners, Detroit, Mich.

ance of the applied water, notwithstanding the apparent constancy of the turbidity of the raw water.

Upon occasion there was decreased efficiency of coagulation, resulting in scanty floc formation which tended to give the applied water an opaque appearance. The change in the character of the water was most discernible when the turbidity of the raw water did not exceed 20 p.p.m. A turbidity in excess of that amount decreased the clarity of the applied water to such a degree that it was impossible to make determinations other than by the standard practice of turbidity comparisons.

The appreciable difference in hours of filter service caused by varying factors of coagulation prompted the consideration of changing the point of application of the concentrated solution of sulphate of alumina.

In accordance with the above decision a 2½-inch feed line was connected to the discharge of the alum dry feed machines and the flow of chemical solution diverted to the effluent end of the intake tunnel, the discharge end of the chemical feed line being submerged to a depth of 5 feet at the central point of the tunnel.

The possible advantages to be derived from changing the point of chemical application were the following: the additional travel of approximately 100 feet through the raw water flume under the low lift pumps and the vigorous mixing supplied by the low lift pumps as the water is discharged into the connecting tunnel between the low lift pumping station and the filtration plant, followed by the slower agitation as the water passes through the mixing chamber.

Constant observation of the applied water at the outlet end of the mixing chamber, after changing the point of application, did not reveal any apparent difference in flocculation, although the resulting increase in hours of filter service was quite appreciable, amounting to from 12 to 15 per cent.

During the months of January, February and March of each year the turbidity of the Detroit river water rarely exceeds 20 p.p.m., the protective covering of ice preventing serious disturbance of Lake St. Clair by wind or rain. At this season of the year conditions are usually more consistent, relative to turbidity and temperature, than at any other season of the year. Therefore, it will be readily understood that a change in the character of the water would not seem to be entirely due to agitation of the Lake water, though local river disturbance is responsible for short periods of increased turbidity.

As a means of demonstrating the practicability of the longer mixing period we have occasionally changed back to the original point of application of the chemical solution, whereupon, following the usual period of settling, there was a marked decrease in hours of filter service.

Convinced of the desirability of a longer mixing period, provision has been made for a permanent installation to convey the chemical solution to the initial point of entrance of the river water.

The relationship between turbidity, rate of filtration and filter service is an important factor in the operation of a mechanical or rapid sand filtration plant.

In the Detroit plant, as in other plants, the length of time a filter will remain in service is governed by the character and quantity of suspended matter in the raw water, efficiency of coagulation and rate of filtration.

When the turbidity of the raw water is unusually low, it is generally found that owing to the presence of organic colloids and the very finely divided state of the suspended particles, coagulation is retarded and sedimentation proportionately decreased by the formation of fine floc, which has relatively low attraction for the foreign matter contained in the water. This condition often prevails in the Detroit plant, particularly during the winter months, when the temperature of the water is but slightly above the freezing point.

In the event of unusually low air temperatures there is a very decided increase in water consumption, prompted by the precautionary practice of the consumers in wasting water to prevent frozen water lines with the attendant expense of repairs. On these occasions the rate of filtration must be increased to meet the water demand. In extremely cold weather this increase will be approximately from 8 to 10 per cent.

During the year 1925 the periodic changes in rate of filtration, occasioned by seasonal demand, varied from a minimum rate of 125 to a maximum of 175 m.g.d. per acre.

The limited storage capacity of the filtered water reservoir, which does not exceed, from the filter plant operating standpoint, more than 15 million gallons, less than two hours normal supply, prohibits operation at a uniformly low rate for any considerable length of time.

On the contrary, it is necessary to keep the filters set at a sufficiently high rate to meet peak loads during certain hours of the day, cutting out or placing filters in service with the fluctuating pumpage.

The result is that during most of the twenty-four-hour day only part of the 80 available filters are in actual service and at a higher rate setting than would be needed if it were not necessary to filter water at approximately the same rate at which it is being pumped into the distribution system. To illustrate this point, at 12 noon on June 25, 1925, 75 filters were being operated at the rate of 166 m.g.d. per acre to meet a peak load of 312 m.g.d. At 12 midnight only 45 filters were in service (at the same rate) to carry a load of 187 m.g.d. The total water filtered on that date was 264.6 million gallons.

The above example indicates an important disadvantage we have had to contend with in the operation of the plant, and no relief from this condition will be afforded until an additional reserve of filtered water has been provided. In this connection the Detroit Department of Water Supply has made provision for the construction of a second filtered water reservoir with a capacity of 20 million gallons. This reservoir will be situated immediately north of the existing filtration plant and the combined available supply from the two reservoirs will total 55 million gallons, or five and one-half hours supply at present normal rates.

The additional reserve of filtered water will enable us to operate the plant at an approximate rate of from 125 to 140 m.g.d. per acre, or 3.0 to 3.5 million gallons per day per filter, which will be of great benefit, inasmuch as it will permit a desirable increase in the period of coagulation and sedimentation, which, in turn, will result in longer filter runs, the use of considerably less wash water and increased bacterial efficiency of the filters.

In regard to the latter condition it is universally recognized that a low rate of filtration is most desirable. In the Detroit plant it is often necessary to increase the rate of filtration in order to provide sufficient water to meet the demand. The undesirability of increasing the rate of filtration, when the filters have been in service for some hours, is well understood. Yet, owing to the limits of operation, we are compelled to make these changes.

Our records of operation offer conclusive evidence of the value of low filtration rates, from the standpoint of bacteriological efficiency and increased filter service.

During the months when the rate of filtration does not exceed 135 m.g.d. per acre, and the turbidity of the raw water is not less than 35 p.p.m. there is an appreciable increase in filter service and

in the bacterial reduction of the filtered water, though a counter effect results from operating at the rates which prevailed during the months of July and August, 1925, viz. 166.3 and 165.8 m.g.d. per acre respectively.

The percentage of decrease in bacterial efficiency of the filters, after increasing the rate of filtration, is largely influenced by the condition of the river water. A turbid water, containing numerous bacteria, will show a higher percentage of bacterial efficiency of the filters than a water containing a relatively low number of bacteria and a small amount of turbid matter.

To counteract the possible harmful effects of operating at the higher rates, a slight increase of chlorin solution is applied to the water, usually $\frac{1}{4}$ pound in excess of normal dosage.

Efficiency of coagulation and sedimentation is essentially important in the process of filtering a water supply. There are two coagulation basins in the Detroit plant, each of 15 million gallons capacity. These basins were designed to provide a subsidence period of more than two hours when the whole plant is operated at its maximum rate.

From observations made, the reader believes that a period of sedimentation of less than two hours is impractical in treatment of the Detroit river water.

To determine the efficiency of the west coagulation basin, in regard to flow and time of retention, studies were made of the currents, by means of surface and depth floats, in 1925. This basin is 505 feet long by 240 feet wide and 16 feet deep, and is of the around the end type.

The applied water is admitted from the mixing chamber through a submerged sluice gate, $8\frac{1}{2}$ feet by 14 feet in size. After entering the basin the water flows against a perforated baffle wall which serves as a distributor. This wall sits on an angle of $12\frac{1}{2}$ degrees.

The current studies, which supplemented preliminary investigations conducted in 1924, showed that peculiar currents and eddies are created throughout the basin.

In some locations of the basin it was found that velocities were four times the average, in others the flow was almost zero. Reverse currents and dead corners were also discovered.

To augment these studies and to endeavor to discover some new facts in relation to basin dispersion, a model coagulation basin was constructed which is a prototype, at a scale of 1 to 20, of the west coagulation basin.

This model basin was operated at various rates of flow until a rate of flow corresponding in physical characteristics to the flow through the large basin was obtained.

After determining this flow several schemes to improve the general flow of water through the basin were experimentally tried. Briefly, these schemes were as follows: an inclined baffie was installed and used in various positions; screens of different mesh were placed in varying positions and changes of flow determined; perforated baffle or stilling basin and submerged weirs were also experimented with and resulting changes carefully noted.

The various tests for current variations were made with surface and submerged floats and color clouds. The obtained results were charted on a system of coördinates at one minute intervals, locations of extreme eddying and dead corners being charted. Dispersion was also determined by dosing with sodium chloride.

These experiments have not been concluded and other methods of determining the most efficient means of controlling the flow and dispersion of the water in the west coagulation basin will be tried until the most practical control has been definitely decided.

Admittedly, conditions of flow in the coagulation basins are not entirely satisfactory, and the adopted method of future control should have the effect of prolonging the period of retention, which at the present time of operation is considerably less than the capacity of the basins would indicate.

These points are purposely stressed because of their close relationship to the general principles of filtration practice.

FILTER BEDS

In the Detroit plant there are 80 filter units, each having an effective sand area of 1088 square feet. The filters are divided into five double rows of eight beds with a pipe gallery between each two rows, the operating floor forming the cover for the pipe galleries. Each bed is $\frac{1}{40}$ of an acre and has a filtering capacity of 4 million gallons at 160 million gallon rate or $4\frac{1}{2}$ million gallons at 180 million gallon rate.

The filtering medium consists of 17 inches of gravel placed around and above the strainer system in even layers, varying in size from 2 inches at the bottom to $\frac{1}{16}$ inch at the top, and 30 inches of sand having an effective size of 0.45 mm. and uniformity coefficient of 1.5.

When the plant was first placed in service the depth of sand in

each filter did not exceed 24 inches. After two months of operation, during which time regular inspection of the beds were made, it was discovernd that "mud balls" were much in evidence in each bed.

The problem of disposing of the mud balls in eighty large filter units was one which caused some concern and involved careful consideration of the method to be pursued, so that the operation would be effectively and economically fulfilled.

The old method of removal by screening was considered impractical, therefore, it was deemed advisable to construct or assemble a mechanical appliance capable of a wide range of operation, in a local sense.

After a brief period of experimental work we procured two 350 r.p.m. portable electric drills, to each of which we assembled the following parts: one six foot length of $\frac{3}{4}$ inch steel shaft, one 10-inch right propeller and one 10-inch left propeller. The blades of the propellers had a 15-inch pitch and were spaced 12 inches apart at the end of the steel shaft.

In preparation for treatment of the sand a portable platform was placed over the wash water troughs which permitted the sand to be treated in a $\frac{1}{16}$ section of the bed without making further changes.

Prior to commencing the actual operation of sand treatment the wash water valve was partly opened and the sand driven into suspension, thus reducing the frictional resistance of the sand to a minimum. The shaft, with propeller blades attached, was then submerged to the required depth and the sand was subjected to a vigorous agitation, created by the reverse action of the two propellers.

The initial operations were carefully observed, inspections being made quite frequently, to make certain that there was no unusual disturbance of the finer gravel.

The results obtained from this method of mud ball treatment fully justified its continuance until the contributory causes of mud ball formation had been eliminated.

The cost of sand treatment did not exceed $20.00 per bed, this amount being inclusive of labor, wash water used and depreciation of equipment.

Mention having been made of the forming of mud balls in the filter beds it is important that an opinion be expressed as to the possible cause of this undesirable condition. As formerly stated the original depth of sand did not exceed 24 inches in each bed. With this depth of sand the distance from the level of the sand to the crest of the wash water troughs was 36 inches.

After a short period of operation it was found that the surface of the sand was becoming heavily laden with very fine silt, which could be attributed to no other reason than the partial ineffectiveness of the wash water, occasioned by the unusual distance which the surface silt had to be raised before being discharged into the wash water troughs.

The constantly increasing accumulation of surface silt necessitated scraping off a light layer of surface sand at altogether too frequent intervals.

In addition to the foregoing difficulties we developed an air condition in the filters which seriously interfered with their operation and was a primary factor in the development of "mud balls."

In the months of March and April, 1924, there was a decided falling off in filter service, due to the character of the water then being treated, the length of the filter runs being reduced to less than 4 hours, in many instances. The decrease in filter service periods was accompanied by a complete air binding of the filters, which, for a brief time, threatened to curtail the general supply of filtered water.

The most harmful effects of the air-binding were experienced in the washing of the filters. It is our practice to crack the wash water valve at the beginning of the wash and after the sand surface has broken evenly gradually bring the wash water to the desired rate. This method of operation was useless when washing an air-bound filter, inasmuch as it was required to open the wash water valve two or three points before air displacement became effective. Notwithstanding the practice of every precaution there were violent sand eruptions during the washing of the filters, which tended to thoroughly mix the surface silt with the general body of the sand. Close observations following the washing of the filters indicated that mud balls were the result of these abnormal conditions.

At a later time it was determined that air-binding of the filters was a mechanical difficulty, which was overcome by making additional pipe installations to prevent pocketing of air in the mercury wells and in the effluent pipe line when the filters were drained for washing.

As a means of preventing the accumulation of silt on the sand surface, sufficient sand was applied to each bed to decrease the distance from the surface of the sand to the crest of the wash water trough from 36 inches to 26 inches. Since the application of additional sand there has been no recurrence of mud balls.

During the past year the construction of a sewage pump and pumping station was completed. This building houses an American Well Works vertical pump with a capacity of 13,000 gallons per minute. The pump is driven by a General Electric 75 H. P. motor. All sewer lines from the filtration plant, low lift pumping station and adjoining catch basins feed into the sewage sump, from which the sewage is pumped into the Detroit River.

The existing source of wash water supply is direct pumpage from the water mains. The irregularity of pumpage, caused by the spasmodic filling of the water tanks during the washing of the filters, made it almost impossible to maintain constant pressure in the water mains from which the filtration plant is drawing its supply of wash water. To provide against the difficulties of operation from this source, an independent supply of wash water is being arranged. Under the changed conditions the wash water will be pumped direct from the filtered water flume, into which the filters on No. 2 Gallery are discharging, thus eliminating the supply from the city main, with its attendent troubles.

The installation of a vertical pump, with a capacity of 12,000 gallons per minute, is nearly completed. This pump will be driven by a 250 H. P., 585 r.p.m. General Electric motor. When placed in service the pump will furnish sufficient wash water to meet all conditions of filter operation.

The complete personnel of the Detroit Filtration Plant consists of the Chief Chemist and Superintendent, one Bacteriologist, four Junior Chemists, one laboratory assistant, one stenographer, one filter foreman, eleven filter operators and eighteen utility men. One Junior Chemist is on duty on each shift.

There are three filter operators on each shift of eight hours. These men work in rotating shifts of four weeks each. The operators are required to work forty-eight hours per week, provision being made for one relief day in each seven days.

WATER WORKS ACCOUNTING AND FINANCING[1]

By Fred Buck[2]

The subject of financing and accounting may, upon first thought, seem rather out of place for one following engineering work, but it was doubtless brought about through my connection with the Public Utilities Commission of the State of Montana. The work brings me in close contact with the operation of all utilities, their annual reports, tariffs, etc., besides often being called upon to make physical valuations of plants for rate-making purposes. In order to make these valuations it usually becomes necessary to go into the book accounts and also to analyze the operating methods and management.

The method of opening a set of books and classifying items to the proper accounts is an old story. This routine is well-established and can be procured in book form from the Commission at Helena. Instead of attacking the subject from this angle, I am going to dwell upon the fact that the manager of the utility must be familiar with both the operating and the accounting in order to make a success of the business. To most of you who are operating the larger plants, you will say, "Of course, anyone knows that is true." While this should be the case, our experience reveals the fact that a large per cent of the plants is taken care of by two heads, one that looks after the accounting and the other taking care of the physical part of the system. These two departments usually operate independently of each other and neither is versed in the other side of the question.

With municipally owned plants this is almost universally the case; the city clerk looks after collections, accounting, etc., while a manager looks after the physical plant. The work of the two branches is not correlated and neither department is posted upon the details of the work of the other.

In order to show you the necessity for this coöperation, let us turn to the diagrammatical analysis of the balance sheet in figure 1 and see how the management of the plant weaves itself into the various

[1]Presented before the Montana Section meeting, April 17, 1926.

[2]Engineer, Public Utilities Commission, Butte, Montana.

items that go to make up operating revenues and operating expenses. The chart follows closely the balance sheet as submitted to us by the utilities in their annual reports.

If the utility is a privately owned one, the top item, or "net income," reflects the final result of management, while the "sinking fund and interest" account tells the whole story for a municipally owned plant. Either of these items is derived from the "gross income" which in turn is the differential between the "operating revenues" and the "operating expenses."

The manager's interest lies in trying to build up the income side of the chart and at the same time keeping down the operating expenses. Naturally, the first impression of the thing we think of in this connection is to raise the rates for service and be niggardly in expenditures, but efficient management will accomplish as much financially and at the same time retain the good will of the public.

The items that make up the revenues are derived from municipal, industrial, commercial and miscellaneous sources. In the first instance, the utility is entitled to revenue from fire plug rentals and the sprinkling of parks and sprinkling and flushing streets. Often with municipally owned plants no charge is made for these services and therefore the burden of maintaining such services falls upon the revenue customers.

We often find that one of the greatest sources of loss comes from the industrial and commercial revenues. The utility may be completely metered, or operating entirely on flat rates or have both metered and unmetered services. We know that in most instances the per capita consumption decreases as the percentage of metered services increases. It therefore follows that if we do not keep the percentage of metered services abreast of the city's growth, there are going to be losses in revenue as well as increased maintenence costs due to a greater consumption of water.

Where flat rates are in vogue, it is essential to have the correct classification of outlets for each customer, for otherwise a utility may lose considerable revenue on account of underbilling the customer. The general run of customers are sufficiently versed in water tariffs to know whether their monthly bills are correct or not and will seldom hesitate to enter a protest where an overcharge has been made, but usually are reluctant to speak up in the case of an undercharge. Consequently the utility, through its manager, must carefully guard this source of revenue and fight for the amounts that are justly due.

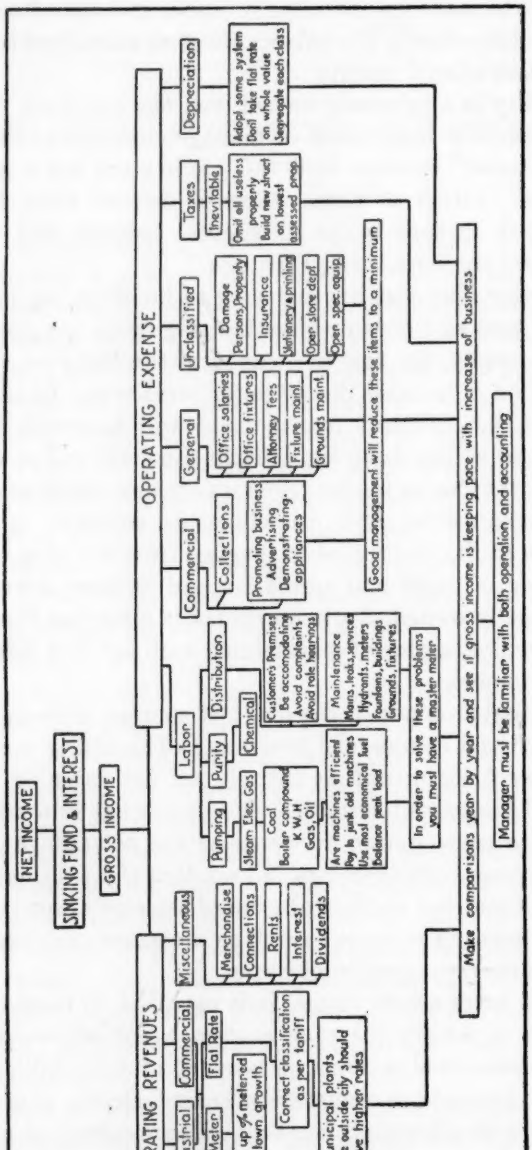
NET INCOME
SINKING FUND & INTEREST
GROSS INCOME
OPERATING REVENUES
Municipal
Industrial
Commercial
Miscellaneous
Fire Plugs
Parks
Sprinkling
Meter
Flat Rate
Keep up % metered with town growth
Correct classification as per tariff
Municipal plants Service outside city should have higher rates
Merchandise
Connections
Rents
Interest
Dividends
OPERATING EXPENSE
Labor
Commercial
General
Unclassified
Taxes
Depreciation
Pumping
Purity
Distribution
Steam Elec Gas
Chemical
Coal Boiler compound K W H Gas, Oil
Are machines efficient Pay to junk old machines Use most economical fuel Balance peak load
Customer's Premises Be accomodating Avoid complaints Avoid rate hearings
Maintenance Mains, leaks, services Hydrants, meters Fountains, buildings Grounds, fixtures
In order to solve these problems you must have a master meter
Collections
Promoting business Advertising Demonstrating appliances
Office salaries
Office fixtures
Attorney fees
Fixture maint
Grounds maint
Damage Persons Property
Insurance
Stationery & printing
Open store dept
Open spec equip
Good management will reduce these items to a minimum
Inevitable
Omit all useless property Build new struct on lowest assessed prop
Adopt same system Don't take flat rate on whole value Segregate each class
Make comparisons year by year and see if gross income is keeping pace with increase of business
Manager must be familiar with both operation and accounting

FIGURE 1

A good example of such a case was called to our attention a short time ago, when a municipally owned plant in a small town was continually losing money and falling short of the sinking fund and land requirements. A citizens' committee took the case in hand and discovered that a good many discriminations were being practiced and in many instances new outlets, such as faucets, bath tubs, wash basins, etc., had been added to the premises since the water department's last survey made several years previous, for which no charge was being made, as the records did not show the added improvements. The survey and revision of the records resulted in sufficient increased revenues to bring the sinking fund requirement up to normal without increasing the approved tariff. This case was an outstanding example of where the accounting and management were under separate heads and the work of the two not coördinated. The segregation resulted in a loss of revenues to the utility.

Customers living outside the city limits should expect to pay higher rates to municipally owned systems as their property is exempt from special taxes levied for the purpose of retiring water bond issues. On several occasions we have found no segregation of rates between in- and out-of-town users.

Miscellaneous revenues may be derived from many sources as the sale of merchandise, profit on making house connections, rents from land, buildings, etc., interest on invested funds, or dividends from stocks, etc. Such sources of revenue may be extended or increased after a careful analysis by the manager.

The above discussion of the items of revenue are called to your attention, not merely to show how the revenues may be increased, but primarily to impress upon you how essential it is for the manager of a water works plant to keep in mind the financial outcome as well as the efficient management of the physical plant itself.

The ultimate goal of the manager in making a study of the other half of figure 1, is to endeavor to cut down the operating expense to a minimum without impairing the efficiency of his plant. Such expenses are usually classified as the costs of pumping, purification, distribution, commercial, general and unclassified costs, taxes and depreciation.

If the system is a pumping plant, a saving, and often times a big saving, can be effected by changing to a more economical fuel, by replacing antiquated engines for more efficient types, or, if electricity is purchased on the peak load system, by balancing the load as much as possible and thereby reducing the peak.

Under the cost of distribution we note the item "be accommodating, avoid kicks and rate hearings." There is perhaps no one thing that will militate against the success of a utility as a dissatisfied public, brought about by unaccommodating officials and discriminating or excessive rates. Once the mind of the general public is poisoned against the utility, it takes a long time to live it down. Rate hearings and complaints of service cost money and usually in the end the utility is forced to make revisions. Such extra costs can often be eliminated through proper management.

We had one case called to our attention for investigation where the manager was a very disagreeable fellow and very discourteous to the public. The whole town was up in arms against the company until they complained of the rates, the service, and in fact everything connected with the operation of the company. This condition resulted in a rate hearing, a sharp reduction in their tariff and a change in management, but did not immediately wipe out the bitter feeling toward the utility. All of this could have been avoided in the first instance by the proper management. These things in turn are reflected in the yearly balance sheet.

The heading of "collections" calls to mind another case where the manager's son officiated as meter reader and collector at a good salary. His duties occupied about six or eight days per month and the balance of the time he was idle, but his salary continued. Similar cases are often fruitful sources wherein operating expenses can be reduced.

I am not going to attempt to discuss each heading, but will touch for a moment the subject "taxes," the inevitable expense. In building new structures, or appurtenances to the system where a choice of location is not material from an engineering standpoint, care should be taken to choose property having the lowest assessed valuation. Also it will often pay to junk or discard entirely old machinery and useless property in order to get away from paying taxes on the same. We have noted about us recently in several instances, the railway companies taking up non-paying branch lines in order to eliminate the taxes and this principle applies to water utilities as well as railroads.

Not long ago I had an occasion to make a physical valuation of a plant which was valued by the company at $300,000. It developed that about one-sixth of this was made up of machinery, buildings and property no longer in use or of no value whatever to the company,

so far as the utility was concerned. Still they are paying taxes on this dead property and charging the same into operating expense.

In this connection it is interesting to note that privately owned water plants in the state, valued at over $9,500,000 pay a total property tax of $91,420. The municipally owned plants are valued at $8,600,000 and pay no tax.

In the matter of "depreciation," we had an interesting case come to our attention recently when the city clerk filed his annual report showing operating revenues of $3000 and a gross deficit of $8800. Examination showed that he had charged off 20 per cent of the value of the plant for depreciation, and stated in a footnote that the system was getting old and it was discovered they were not reserving a sufficient fund for depreciation. In place of revising their depreciation charge and spreading it over several years, he had charged it all off during the one year and came out sadly in the red.

We find in a good many cases that the system is not provided with a master meter and consequently there are no data on the consumption. Without such a meter, a knowledge of the items of pumping and distribution cannot be had which in turn may be reflected seriously in operating expense.

If a plant manager will set up a financial chart similar in general character to this one, but fitted to his local conditions, and then compare the final results, year after year, it will be of great value to him in more efficiently handling the system. Such a plan can, at least, do no harm and will be far better than the haphazard methods usually found in practice.

Before coming to a close, I thought you might be interested in learning something of the water works plants in the State of Montana. Altogether there are 107 that are classed as public utilities and report to us as such; 73 of these are municipally owned, and 34 are private companies. The total investment represents $18,200,000, 47 per cent of which are city plant investments and 53 per cent company plants. The indebtedness of city owned plants, approximately $5,000,000, represents 58½ per cent of their total investment. The gross profits, as earned last year, would pay 6 per cent interest on this indebtedness and retire the total bonds in forty-three years, providing none were retired in the meantime and the sinking fund drew no interest. Last year the municipally owned plants showed a ratio of gross profits to investment of 4.85 per cent, while the ratio for private plants was 3.0 per cent. This ratio reflects a more

healthy financial condition in municipally owned plants than in privately owned, but on the other hand they are exempt from all forms of taxes which would account for a part of the difference in the two percentages.

The above figures are somewhat foreign to my main topic, but nevertheless are interesting facts as shown by the annual reports of the water works utilities in Montana.

As stated in the beginning, the object of this discourse was not to tell you which accounts should be debited or credited with items of expense or money collected, nor how to establish a set of book accounts, as the title of my talk might suggest; but to impress upon you how essential it is for the manager of a plant to be familiar and have at his finger tips, knowledge of both the financial and physical operations in order to correlate the two and thus end the year with a creditable balance sheet. Those who grope in the dark without having some sort of plan to follow, never progress very far in their undertakings.

UNITED STATES PUBLIC HEALTH SERVICE AND MUNICIPAL WATER SUPPLIES[1]

By Isador W. Mendelsohn[2]

On February 15, 1893, Congress approved an act entitled: "An act granting additional quarantine powers and imposing additional duties upon the Marine Hospital Service," which provides, in part, in section 3 that the Secretary of the Treasury shall, if in his judgment it is necessary and proper, make such additional rules and regulations supplementary to State and Municipal regulations as are necessary to prevent the introduction of contagious and infectious diseases into the United States from foreign countries, or into one State or Territory or the District of Columbia from another State or Territory or the District of Columbia. The spread of disease through water supplies was, and is, considered of great public health importance. Accordingly, based upon this, and subsequent acts, the revised Interstate Quarantine Regulations of the United States were promulgated on May 3, 1921, containing section 18 stating "water provided by any person, firm, company, or corporation for drinking or culinary purposes on any car, vessel or other conveyance while engaged in interstate traffic shall be from a source which is approved by the Surgeon General of the United States Public Health Service as producing water of satisfactory sanitary quality and safety."

To enforce this regulation, a certification procedure was evolved which has been modified from time to time. The present certification procedure was established in 1917–18, and is based upon the principle that in each state the State Department of Health as the regularly constituted authority is responsible for the sanitary quality and safety of the public water supplies. The procedure was approved by the Conference of State Sanitary Engineers and the Conference of State and Territorial Health Officers and was then established by

[1] Presented before the Rocky Mountain Section, February 23, 1926.

[2] Associate Sanitary Engineer, United States Public Health Service, Chicago, Ill.

the United States Public Health Service. By this procedure water supplies in a state used for drinking and culinary purposes on common carriers operating interstate are surveyed annually by competent personnel of the State Department of Health and chemical and bacteriological analyses of the waters are made by the Department. The character of the sanitary survey and the analyses are set forth in Drinking Water Standards,[3] which were approved by the two conferences of state health authorities mentioned as well as associations concerned with the supply of drinking water, promulgated by the Secretary of the Treasury on June 20, 1925, and administered by the United States Public Health Service. From the data collected, the State Health Officer recommends to the Surgeon General of the United States Public Health Service approval or disapproval of the use of the water supplies, and the Surgeon General carries these recommendations out in accordance with the procedure agreed upon. In this manner one uniform policy regarding all of these waters is administered in all of the 48 states of this nation with maximum use of regularly constituted local authorities at minimum expense.

In each State Department of Health, the water supply work is carried out by a Division of Sanitary Engineering. When such a division is not established or where personnel are not available to carry out the work, it is the policy of the United States Public Health Service to assist the State Department of Health in obtaining such a division through the temporary loan of sanitary engineers and through the appointment of collaborating sanitary engineers in state departments of health at nominal salaries with travel expense funds. Largely through such efforts, sanitary engineering divisions have been established in fourteen state health departments since 1918; and about thirty states, with limited funds, are being assisted.

In Colorado, sanitary engineers of the United States Public Health Service have been loaned to the State Board of Health for short periods since 1922. This assistance was instrumental in bringing Dana E. Kepner, the present state sanitary engineer, to the Board in the summer of 1924. His fine work has resulted in the establishment of a sanitary engineering division in the State Board of

[3] Drinking Water Standards. Reprint No. 1029. Public Health Reports, April 10, 1925.

Health in 1925 and in the improvement of public water supplies, sewerage systems and other sanitary works in the state.

In New Mexico, the creation of a division of sanitary engineering in the State Bureau of Public Health was brought about in 1919 largely through the efforts of the United States Public Health Service. Since then capable state sanitary engineers have been employed, the present engineer being Paul S. Fox.

Wyoming has no division of sanitary engineering in the State Department of Public Health and Vital Statistics. As a result sanitary engineers of the United States Health Service have been loaned to the department at various times since 1921 to make sanitary surveys of water supplies, sewerage systems, etc.

As regards the present status of the certification procedure in the three states, table 1 shows that of the 81 water supplies used by the railroads for drinking and culinary purposes in interstate traffic,

TABLE 1

Data retarding certification of interstate carrier water supplies in Colorado, New Mexico and Wyoming, June 30, 1925

STATE	WATER SUPPLY OWNERSHIP				WATER SUPPLIES CERTIFIED	
	Public	Private	Railroad	Total	Number	Per cent
Colorado	28	3	8	39	35	90
New Mexico	10	0	15	25	24	96
Wyoming	9	2	6	17	15	88

74 or 91 per cent are certified, and 52 or 64 per cent are owned by public or private agencies, the remainder by the railroads. This record is a good one, especially since the large majority of the travellers on trains use the water from certified supplies.

The Drinking Water Standards are intended for interstate carrier water supplies only, and are not proposed for more general application. In actual practice, these standards will exert a great and favorable influence upon the quality and purity of all water supplies in this nation. The standards were arrived at after two years of work by a committee of forty scientists and health officials representative of every phase of the question and each section of the country. These standards are the most authoritative present judgment on this subject.

They are published in full in the Manual of Water Works Practice.

In conclusion it may be stated that "The general effect of the whole certification procedure and the strengthening of the position of the State sanitary engineering divisions which has resulted have played no small part in contributing to the reductions of the typhoid fever rates during the past decade."[4]

[4] Safeguarding the Sanitary Quality of Drinking and Culinary Water Supplied in Interstate Carriers. E. C. Sullivan, Asst. Sanitary Engineer, U. S. Public Health Service. Reprint No. 935, Public Health Reports, July 4, 1924.

REPORT OF SECTIONAL COMMITTEE ON MANHOLE FRAMES AND COVERS OF AMERICAN ENGINEERING STANDARDS COMMITTEE[1]

The following report will indicate, briefly, progress made to date by the Sectional Committee on Manhole Frames and Covers of the American Engineering Standards Committee.

The Sectional Committee organized October 27, 1925 with L. B. Fish of the American Telephone and Telegraph Co., Chairman, and C. H. Shaw of the New York Edison Company, Secretary.

A sub-committee has been appointed on Manhole Frames and Covers for Sewer, Water, Gas, Steam and Air with W. W. Brush, a member of this Association, as Chairman.

A survey of the situation shows that there are now in use a great variety of manhole castings, some of which are doubtless inadequate in design and others too heavy. This results in waste of metal, losses due to breakage, added cost of duplication of patterns, delays in manufacture and increase labor costs.

It would appear, therefore, that there is ample opportunity for this Committee to assist in developing suitable standards for manhole frames and covers and thereby eliminate some of the waste and unnecessary expense now incurred.

Respectfully submitted,

Frank A. Marston,

Representative of the American Water Works Association.

[1] Presented before the Buffalo Convention, June 8, 1926.

HISTORY OF DUBUQUE'S WATER PLANT[1]

By J. W. McEvoy[2]

Overlooking a perfect landscape of the scenic Mississippi River, the city of Dubuque was founded in the year 1833. It was not incorporated, however, until eight years later. Mining was the chief industry for many years, and was carried on under great difficulties due to the powerful strata of water which covered the large beds of ore that were found. As the years progressed many different methods of excavating the ore were employed. Among them, a company headed by Silah Chamberlain and N. W. Kimball was organized for the purpose of blasting a tunnel under a large hill, between what is now known as Kaufman Ave. and West Dubuque, to drain that territory.

Their plans were that by blasting this tunnel below the level of the standing water they could lower the water head, thus causing the water to flow through this tunnel into a ravine at a lower level. By this method they could excavate the lead without being hampered by the water that stood at a higher level.

This was a mistaken idea, however, for in carrying out their plans, they not only failed to lower the water head, but they also tapped a water vein which flow approximately 400,000 gallons per day, thus forming an uncontrollable body of water. This waste of water continued for more than two years before this same company conceived the idea of converting this tremendous loss of water into a water works. They then petitioned the city council for a franchise, and on December 16, 1870, W. J. Knight, as mayor, signed an ordinance giving this company a franchise to operate a water works under the name of the Dubuque Water Company, reserving the right to purchase this plant at the expiration of twenty years. This franchise required them to furnish water by means of gravity pressure until an increase in consumption called for pumping equipment.

In the year 1880 the demand for water supply increased to the hill districts which gravity pressure failed to reach. An arrangement

[1] Presented before the Iowa Section meeting, December 4, 1925.

[2] Superintendent, Water Works, Dubuque, Iowa.

was then made with the owners of the old Lormier Hotel, located on Bluff and Eighth Streets, to install a small pump in their basement. A large wooden tank was then constructed at Julien and Wilson Avenue to hold the water thus pumped, and to serve the hill district and those below that elevation with an adequate water supply.

In 1888 a pumping station was built at the foot of 8th Street and a 400,000 gallon standpipe was erected on Delhi Street in 1889, in order to supply water to property at a higher elevation than the old wooden tank could furnish. This supply was taken from an artesian well that had been drilled at that pumping station.

One year later it was found necessary to use pumping equipment in place of gravity pressure throughout the main part of the city. A new pumping station was erected at Eagle Point and equipped with two 2,000,000 gallon steam pumps and two 100 H.P. power boilers.

This station was first supplied from a group of driven wells 2 inches in diameter driven in the sand, but was found to be a failure due to the wells filling with sand and corroding. A 16-inch line was then laid from the pumps to a cistern near the river bank and a 16-inch line from this cistern to the river. This cistern was used to take suction for the pumps, which pumped directly into the mains. This plan was also found to be unreliable on account of the low stage of water in the river at certain times of the year, and the great objection to the quality of water being served. Then two artesian wells were drilled to a depth of about 1300 feet which was the main source of supply. This new improvement gave satisfactory service for only a few years, due to the fact that sanitary sewers had been extended throughout the main part of the city, and the consumption of water had increased to such an extent that a satisfactory supply was not available. These conditions brought about an agitation among the citizens who wished to purchase the water plant from the original company and make necessary improvements to meet the demand.

This was the situation which existed when a local syndicate was formed about 1896 with the purpose of buying and improving the property. This syndicate did not effect the purchase until 1898, when they rebuilt Eagle Point Station by enlarging the building, adding a new 5 million gallon Holly steam pump, one new steam engine and generator, and one 125 H. P. boiler. In addition to this, they made extensive improvements in the extension of water mains.

After the Eagle Point Pumping Station had been modernized they drew their attention to the other water works property. At the old

water level, off of Kaufmann Avenue, a new pumping station was erected, which was connected with a 12-inch water main to Delhi Street standpipe. This construction eliminated the need of the former Eighth Street Station, whose supply had been furnished by an artesian well which was fast failing to meet the demand.

The sentiment for municipal ownership was crystallized by a series of editorials in the daily papers which brought matters to a crisis. A special election was called by the city council, giving the people the privilege of voting for municipal ownership. The result of the election was a large majority in favor of municipal ownership. After the special election had been held and the vote canvassed and approved by the city council they at once proceeded to purchase the water works by tendering an offer of $150,000 which was refused by the owners. They agreed to a plan, however, to settle the matter by arbitration. A board consisting of five members were accepted, two members being selected by the city, two by the water company and the fifth by the other four members. The price agreed upon by a majority of this board was to be accepted by both interested parties. After many sessions of this board, each side being represented by hydraulic engineers and attorneys, a price of $545,000 was agreed upon. This price included all property, buildings and equipment, and the completion of all work already under construction. On June 1, 1900 the holdings of the Dubuque Water Company were transferred to the City of Dubuque under the name of the Dubuque City Water Works, payments were made by a bond issue of $545,000 which was redeemed by a two mill tax levy extending over a period of twenty years.

A board of water works trustees were then appointed as managers. Very little improvements were made other than extension to water mains for the first seven years. This board resigned in 1907. A new board of trustees was then appointed. On taking charge they found a very limited water supply. This condition was improved by a number of 6-inch wells driven into the sand to an average depth of about 90 feet. This increase in supply with the two artesian wells already in use, gave a satisfactory supply until 1913, when the increase in consumption and decrease in supply from the sand wells caused another shortage. A large sand well 100 feet deep and 8 feet in diameter was then sunk with the thought of securing a supply of 3,000,000 gallons per day. On a careful test the yield was up to their expectation, but in a few years this well also filled up with a

fine sand which held the water back from the pump to such an extent that it was pumping nearly as much sand as water, and was abandoned in 1918. Two additional artesian wells were then drilled to a depth of 1450 feet. In the mean time more 6-inch sand wells were driven making the source of supply 4 artesian and 21 sand wells at the low pressure station and the level tunnel supply for the high pressure station. The trustees, realizing the need for greater storage to meet every emergency, built in 1914 a 7½ million gallon concrete reservoir on the hill near W. 3rd Street at an elevation of 230 feet, which increased the pressure throughout the city from 40 to 85 pounds. It was never kept filled on account of an algae growth which formed in the water thus causing the reservoir to be drained and cleaned two or three times a month. This condition existed until 1922 when the present city council had a cover placed over the top which eliminated all trouble from this growth, and made it possible to keep the reservoir filled to any stage desired.

The trustees made many other improvements, such as installing a 6,000,000 gallon Snow and 3,000,000 gallon centrifugal pump, and a 300 K. W. turbine 350 H. P. water tube boiler at Eagle Point Station. They also built an addition to the level station and added one Prescott electric driven 2,000,000 gallon pump. They were unable, however, to keep step with the other city improvements, as their financial condition would not warrant the extending of mains, and the officers would not consent to any indebtedness to be carried by the water department.

The office of trustees was abolished by a change in the form of government to the city manager plan. About that time the National Board of Fire Underwriters made a survey of the water works and recommended a number of improvements covering all branches of the departments. This meant the expenditure of a large amount of money.

After a careful investigation by the city council and manager, the recommendations of the Fire Underwriters were approved. Engineers were employed and contracts were awarded for buildings and equipment. Work was started in 1923 and finished the beginning of 1925. $375,000 in bonds were sold to cover the cost of the new improvements, including the covering of the W. 3rd Street Reservoir. The improvements consisted of a new fire proof pumping station at Eagle Point, electric driven 7,300,000 gallons centrifugal pump, two 2500 cubic feet air compressor, venturi meter, one artesian well

1500 feet deep, 30-inch discharge line, and a new fire proof building at W. 3rd Street, two 3,000,000 gallon centrifugal pumps, venturi meter, and automatic electrical equipment.

In taking over the water works on June 1, 1900 the city found itself in possession of 44 miles of water mains, 340 fire hydrants, 549 gate valves and 1854 taps. During the first 20 years under management of a board of trustees, there were added to the distribution system 22 miles of mains, 98 fire hydrants, 358 gate valves and 3615 meters. The system is now 99½ per cent metered. Since 1920 up to the present time under the city manager plan of government we have added 29 miles of mains, 243 fire hydrants, 690 valves and 3134 meters, making our distribution system consist of:

	Increase since 1920 per cent
95 miles of mains	40
681 fire hydrants	56
1587 valves	77
7621 meters	40

ANNUAL REPORT OF THE TREASURER, 1925

I submit herewith my report as Treasurer of the American Water Works Association for the calendar year 1925.

The funds of the Association are on deposit with the United States Mortgage and Trust Company at their bank located at 55 Cedar Street, New York City. This bank was selected in 1921 by vote of the Executive Committee.

RECEIPTS AND DISBURSEMENTS, JANUARY 1 THROUGH DECEMBER 31, 1925

Receipts

Balance on hand Jan. 1, 1925	$6,522.59	
Received from Secretary	37,622.72	
Interest on deposits	217.31	
Interest on investments	810.00	
Cancellation of check No. 2143	1.11	
Total		$45,173.73

Disbursements

Expended in payment of vouchers aggregating 399 in number and comprising vouchers 1872 through 2312 both inclusive, except voucher 2139 for $5.10, the check for this voucher having been accidentally destroyed by the payee; and voucher 1951 for $8000, representing a transfer to the time account in the bank, as noted below.	$40,822.80	
(Checks bearing the same numbers as the vouchers have been drawn, with the exception of those vouchers which cover charges made by the bank on check collections, and the amount of such vouchers is set forth below.)		
Exchange on checks as charged by the bank, including charge of $1.00 for December 1925, for which a voucher was drawn in 1926	11.87	
Deduction for five checks returned by the bank for various reasons	37.75	
Total		$40,872.42
Balance, January 1, 1926		$4,301.31

In the above receipts and disbursements no entry is made of $8,000 which was temporarily transferred to a time account of the United States Mortgage and Trust Company, and which was later again credited to the drawing account. This transfer was for the purpose of increasing the interest received for the money on deposit, and voucher No. 1951 covered the transfer of this money.

Cash balance at close of business December 31, 1925, shown by December statement of United States Mortgage and Trust Company			$5,104.34
From this balance there should be deducted for unreturned checks, the following:			
Drawn in 1924:			
No. 1448	$0.18		
No. 1512	1.57		
No. 1546	3.96		
No. 1578	1.74		
Drawn in 1925:			
No. 2123	$2.38		
No. 2149	30.00		
No. 2272	13.05		
No. 2274	5.05		
No. 2275	2.30		
No. 2299	150.00		
No. 2300	100.00		
No. 2302	111.18		
No. 2303	24.00		
No. 2304	39.38		
No. 2305	50.00		
No. 2306	17.22		
No. 2307	8.85		
No. 2308	2.41		
No. 2309	2.06		
No. 2310	10.08		
No. 2311	2.07		
No. 2312	225.55		
Total		$803.03	
Net bank balance			$4,301.31

The receipt for interest on investments includes $270 which became due at various dates towards the end of 1924, but the coupons were not deposited until February 2, 1925.

The receipted vouchers have been returned to the secretary. The cancelled checks and duplicate deposit slips, with the book of the treasurer, have been submitted to the auditor and returned by him.

The permanent fund has not been changed during the year and consists of the following bonds which are in a safe deposit box at the United States Safe Deposit Company, 32 Liberty Street, New York City.

4—$1000 Dominion of Canada 5%	$4,000
1—$1000 U. S. Liberty 2d, 4¼%	1,000
2—$1000 U. S. Liberty 3d, 4¼%	2,000
2—$1000 U. S. Liberty 4th, 4¼%	2,000
3—$1000 U. S. Treasury 4¼%	3,000
Par value of permanent fund	$12,000
Interest on permanent fund	$540

The treasurer received no salary, and is under $10,000 bond, which has been placed by the Finance Committee.

Wm. W. Brush,
Treasurer.

ANNUAL REPORT OF THE TREASURER OF THE ELECTROLYSIS FUND, 1925

I submit herewith my report as Treasurer of the American Water Works Association, for the electrolysis fund, for the calendar year 1925.

The electrolysis fund is on deposit with the United States Mortgage and Trust Company at their bank located at 55 Cedar Street, New York City.

RECEIPTS AND DISBURSEMENTS, JANUARY 1, 1925, THROUGH DECEMBER 31, 1925

Receipts		
Balance on hand January 1, 1925	$1,278.71	
Interest on deposits	23.01	
Total		$1,301.72
Disbursements		
Payment to Albert F. Ganz, Inc. Check No. 20.	$113.80	
Total		113.80
Balance, January 1, 1926		$1,187.92

This balance is the same as that shown by the bank notice in its December, 1925, statement.

Wm. W. Brush,
Treasurer.

Walter H. Van Winkle

Died July 16, 1926

One of the best known and widely beloved figures in water works circles, Walter H. Van Winkle, has passed away. For many years his handling of the transportation details to our conventions and to those of our sister society, the New England Water Works Association, was so admirable that all of us who took advantage of his efforts have been under personal obligations for his work in our behalf.

In early life he was connected with the water works of Newark, N. J., where he was born on November 20, 1856. This early training in the practical affairs of water works administration gave him an appreciation of the problems of the superintendent and manager which stood him in good stead when he entered the water works supply business.

He left the Newark Water Department to become associated with the A. P. Smith Manufacturing Company, and later joined the Neptune Meter Company. Finally he took part in the incorporation of the Water Works Equipment Company, of which he became president and general manager. In these various business capacities he became widely known. His knowledge of water works affairs was coupled with a genial character and desire to be a real help, so far as lay in his power, to water works men. Smilingly, quietly and tactfully he helped to make smooth the way of many of us, in Association matters and in our personal affairs as water works men. This was recognized when he was elected President of the Water Works Manufacturers Association for a term, but probably few of us realized our indebtedness to him until we were shocked to learn of his death from apoplexy at his fishing camp at Belgrade Lake, Me., on July 16.

His many friends made during his long connection with our Association join with its officers in expressing their sympathy with his widow, Mrs. Florence B. Van Winkle, and his son, Walter H. Van Winkle.

ALLAN W. CUDDEBACK,
President.

MEMBERSHIP LIST

The Publication Committee has decided to publish in the JOURNAL from time to time a list of additions to and resignations from the membership of the Association. By this procedure the reader will have available a more timely list of members than was possible through the publication only once a year of a membership supplement. The names which follow are printed on perforated sheets so that these sheets may be removed from the JOURNAL and added to the last Supplement issued. The Supplement will be published in the future every three to five years.

MALCOLM PIRNIE, *Chairman,*
ABEL WOLMAN, *Editor,*
for the Publication Committee.

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ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Pressure Water Filter. Chem. & Met. Eng., 33: 5, 310, May, 1926. A new design filter has been brought out by the Cochrane Corp. Strainer heads and collecting manifolds are eliminated. Imbedded in the gravel is inverted open cone; water is withdrawn through pipe at apex. Velocity of water through the gravel is higher than through sand bed, and in backwashing all materials are lifted. Should it be desired to remove the filtering material, as is sometimes necessary when filtering greasy water, sand and gravel can be dropped out by opening a gate at bottom of filter.—*John R. Baylis.*

Preventing Corrosion with Protective Coatings. THOMAS W. HIND. Chem. & Met. Eng., 33: 5, 306, May, 1926. Coatings with a bitumen base have given good results against corrosion by water, electrolysis, acids, and alkalies.—*John R. Baylis.*

Testing Corrosion of Iron. T. FUJIHARA. Chem. & Met. Eng., 33: 6, 346, June, 1926. The author claims to have discovered a corrosive mixture in which various kinds of iron can be differentiated in respect to their purity. Mixture consists of equal parts of distilled water and ethyl alcohol.—*John R. Baylis.*

Economics of the Chlorine Industry. D. A. PRITCHARD. Chem. & Met. Eng., 33: 6, 350–3, June, 1926. Electrolytic caustic soda and caustic potash, in so far as chlorine industry is concerned, are incident to manufacture of chlorine. Author concludes that local production of chlorine is impractical The cells are a delicate mechanism and require expert chemical and mechanical supervision. Production must be continuous. About 65 per cent of chlorine gas manufactured in United States and Canada is consumed by paper industry; 22 per cent in textile industries; 10 per cent in sanitation; and remaining 3 per cent in all other uses. Chlorine is used in over 6,000 cities in North America for chlorination of drinking water, sewage, bathing beaches, swimming pools and garbage odors, and for other sanitary purposes.—*John R. Baylis.*

Indurating Wood with Sulphur. W. H. KOBBE. Chem. & Met. Eng., 33: 6, 354-6, June, 1926. Absorption of molten brimstone preserves wood, har-

dens and strengthens it, and gives it acid-resisting properties.—*John R. Baylis.*

Corrosion Theories and Facts. P. D. Schenck. Chem. & Met. Eng., 33: 6, 357, June, 1926. The confusion resulting from publication of tests made under widely varying conditions makes it difficult for engineer to arrive at decision as to most suitable material for a specific purpose. Value of an alloy cannot be determined by laboratory tests unless these are so designed as to duplicate service conditions. Occasionally a very minute percentage of some element will greatly affect corrosion rate. In many instances, simplest and most satisfactory method of determining proper metal to use is to place either a sample or a small piece of apparatus in an actually operating plant under service conditions. Electrolytic action between dissimilar metals frequently increases rate of corrosion.—*John R. Baylis.*

Low Temperature Carbonization and Steam Generation. Abstract from a paper by David Brownlie. Chem. & Met. Eng., 33: 6, 360–1, June, 1926. It is not good practice to fire a boiler with coal containing considerable moisture. Every pound of water carried as moisture in fuel takes about 1,250 B.t.u. in its evaporation and superheat. Application of low temperature carbonization to boiler firing operations is similar to that of drying the fuel except that the tar oils are removed as well as the water. Coal before being fed to stoker or to pulverizing mill is led through a retort in which it is heated by hot waste gases from boiler or by superheated steam to about 1,000°F., for a sufficient length of time to expel about two-thirds of volatile content and all moisture. Approximate yields from one ton of non-caking German steam coal are 40,000 cubic feet of low grade gas of 110 B.t.u. per cubic feet, 16 to 20 gallons of tar oils, and 1,568 pounds of stoker fuel. Nine plants have been built in Germany and Norway. Experiments have been conducted by C. B. Wisner of the Carbocite Company, Canton, Ohio, in which coal is heated first to 600°F. to drive off moisture and then to 900°. This is said to yield 2,640 cubic feet of gas of 880 B.t.u., one gallon of light oil, 30 gallons tar oil, 55 pounds ammonia liquor and 1,590 pounds semi-coke. Another experiment is being conducted at the Lakeside Station of the Milwaukee central station company.—*John R. Baylis.*

The Work of the Quebec Streams Commission. O. Lefebvre. Proc. Am. Soc. Civ. Eng., 52: 5, 895-910, May, 1926. Until 1910, there were practically no data regarding streams of Province. In 1913, systematic organization for flow measurements was instituted, and gauging stations were established on principal streams. Commission has investigated for Department of Lands and Forests great number of water power sites. Several storage dams have been constructed at cost of $7,500,000, from which Commission receives annual income of about $685,000.—*John R. Baylis.*

Developments of the Hydro-Electric Power Commission of Ontario. Frederick A. Gaby. Proc. Am. Soc. Civ. Eng., 52: 5, 911-41, May, 1926. Author gives brief description of power developments of Hydro-Electric Power Com-

mission of Ontario. It is now operating 23 plants and distributing about 800,000 h.p. The Queenston-Chippewa development is described somewhat in detail.—*John R. Baylis.*

Straight Line Plotting of Skew Frequency Data. R. D. GOODRICH. Proc. Am. Soc. Civ. Eng., **52**: 6, 1063-1105. August, 1926. Author gives equations for duration and frequency curves, and for expressing variations in occurrence of phenomena which follow Skew Frequency Laws as to their distribution. Equations are particularly applicable to plotting of hydraulic data. Equations of duration curve are such that a curve can always be plotted as a straight line function of data that follow various skew frequency laws. One general equation is given, which can be simplified for the condition of finite or of infinite limits. Several examples of use of these equations in plotting of curves on a new type of skew frequency paper are shown. Ordinary and logarithmic coordinate paper may also be used. The equations and methods may be used by any one, as the work is largely graphical and most of the difficulties and objections to the use of curves and equations based on statistical methods of analysis are obviated.—*John R. Baylis.*

Cost of Diesel Engine Operation at New Iberia, La. Power, **63**: 25, 965, June 22, 1926. Operation of two 400-h.p. Diesel Engines, direct connected to a 334-kva. generator and a direct-current exciter has been economically satisfactory. For March 1926 total output was 151,600 kw. hrs. and total cost per kilowatt hour, $0.0133.—*Aug. G. Nolte.*

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Diesel Operates at 900 r.p.m. Power, 63: 26, 1010, June 29, 1926. New Foos engine has maximum rating of 40 h.p. per cylinder at 900 r.p.m. High speeds in special gasoline engines are not unusual, but problem of increasing revolutions of the Diesel unit above 400 has been a difficult one. The gasoline draws in a prepared mixture of air and gasoline vapor and engine speed is limited solely by rate of ignition of this mixture. Fuel for the Diesel must be introduced into cylinder in its raw state, and in place of a single ignition and combustion process, must be vaporized through the absorption of heat from its compressed-air charge. The new engine is entirely inclosed, no moving parts save extension shaft coupling being visible. Complete tests at various loads and over entire speed range have indicated excellent operation, with unusually high mechanical and thermal economies. Fuel consumption averaged 0.45 pounds per brake horsepower. In power-plant field, new unit is intended to meet the demand for a standby or emergency prime mover.—*Aug. G. Nolte.*

Boiler Feed-Water Purification—1. Natural Waters and Their Impurities SHEPPARD T. POWELL. Power, **64**: 1, 12, July 6, 1926. Introductory to series of articles by the author on boiler feed-water purification. Tells in a clear and concise manner, of what impurities are found in natural waters, of how they get there, and of troubles to which they give rise in boiler operation. Scale formation and losses therefrom are discussed. The text is augmented with graphs and tables. **2. Getting Rid of Impurities by Sedimentation and Coagulation** Power, **64**: 2, 49, July 13, 1926. Oldest known method of water purification is removal of suspended solids by subsidence. Rate of disposition of a solid body depends upon its specific gravity, its shape and size, and upon viscosity of the water. Settling basins may be classified as either continuous or intermittent. Former are used generally where demand for water is relatively steady and latter where demand is uneven. Tanks operating intermittently are used to a great extent at wayside railroad stations and at small stationary plants. Usual method of operation is to admit water at bottom and to remove clarified water by means of a "swimming" pipe with free end slightly below the surface. Basin through which water flows continuously may be either circular or rectangular. Velocity of flow through basin should be kept uniform. Primary consideration in design of a subsidence basin should be permissible period of detention for removal of settleable solids at maximum rate of flow. From four to twenty-four hours of subsidence may be employed. The depth of subsidence basin is not of great importance except where provision must be made to permit building up of deep deposits between cleanings. Removal of suspended solids by sedimentation is not a complete process and should always be followed, if possible, by a more efficient system. Natural subsidence will remove the relatively coarse suspended solids, but there is a definite limit to the length of the subsidence period beyond which it is not practical to go. Much finely divided material, such as clays and similar substances, is frequently present in surface waters and may remain suspended for a long time unless coalescence occurs to larger aggregates which may be removed by settling or filtration. Removal of these very fine suspensions may be effected by coagulation induced by addition of certain chemicals to the water. The most important coagulants are commercial aluminum sulphate (filter alum) and ferrous sulphate and lime. Recently, sodium aluminate, alumino-ferric, and other forms of aluminum salts have been tried out with some success. When certain of these soluble metallic salts are added to artificially prepared or naturally alkaline waters, chemical reactions take place and gelatinous substances are formed whose sponge-like structure affords large surface areas to which colloidal or semicolloidal particles may adhere. When water that has been coagulated passes through sand, or other filter materials, the flocculated chemical is strained from the water and forms a gelatinous mat or cover on the surface of the filter medium through which water passes while suspended material is entrained and thus removed. Alum and other coagulating substances increase the permanent hardness and may also materially increase the corrosiveness of the water treated. The amount of coagulant required to effect good clarification varies with nature and amounts of suspended and of soluble solids contained in the water, normal range being from 0.5 grain to about 2 grains per gallon. **Pri-**

mary objects of coagulation and settling basins are, first to mix thoroughly water and chemicals in order that chemical reactions may be completed, and thereafter to retain the water sufficiently long to deposit the majority of the coagulated matter. Dorr Clarifier unit is suitable for the treatment of boiler feed water, consisting primarily of a specially designed tank in which suspended solids may be collected and concentrated at a central point and sludge removed continuously or intermittently as desired. Incoming stream of liquid flows horizontally over entire area of tank and clarified effluent is discharged at opposite side. Hardinge super-thickener and clarifier serves to remove suspended solids continuously and at the same time to filter the water. Both clarifiers are illustrated and fully described. Chemical coagulants should be applied under due supervision because overdosing with alum or other coagulants may result in acid water and cause serious operating difficulties. 3. **Filtration by Gravity and Pressure Filters.** Power, 64: 3, 93, July 20, 1926. Filtration is the act of passing liquid through a porous material for purpose of removing suspended matter. Sand, coke, charcoal, excelsior, shavings, marble, magnetite, canvas, and other filter media have been used. Slow sand filters are beds of fine sand, ranging in depth from 18 to 36 inches, resting on some form of underdrainage system, through which water is passed at relatively slow rates (two to five gallons per square foot of filter area per hour). This process is not well suited for clarification of boiler feed-water. Rapid sand filters are units operated at high rates (two to five gallons per square foot of filter area per minute) with aid of coagulant: when surface of sand becomes fouled it is washed by sending reversed flow of clean water through it. This process is applicable to conditioning of feed water, either alone or as an adjunct to softening or other processes. Pressure filters are essentially the same as rapid sand filters, except that filter material is contained in closed steel tank and water is forced through filter under pressure. This form of filtration is especially favorable for treatment of feed-water. Pressure filter units are built in two forms, horizontal and vertical. Former adaptable primarily for filtering relatively small amounts of water and latter for greater volumes. Vertical pressure filters range in size from 12 to 96 inches in diameter and horizontal, from 6 to 8 feet in diameter and from 8 to 25 feet in length. Results obtained from any form of water purification will be proportional directly to care exercised by operator. Routine tests of raw and of treated water and records of essential operating data are required. Filtering is warranted whenever feed-water contains an appreciable amount of suspended solids. Finely divided suspended solid matter in feed-water is an important factor in foaming and priming of boiler water, increases blowdown, and is a freqent cause of burned tubes. Cost of filtration fluctuates widely for different systems and different operating conditions, and ranges from six mils to four cents per thousand gallons of water treated. Different types of filters are illustrated and their operation fully explained. —*Aug. G. Nolte.*

New Washington Filter Plant. P. O. Macqueen. Pub. Works, 57: 197–202, 1926. New rapid sand filtration plant of 80 million gallons capacity having very compact layout is described. Level in clear water reservoir

controls rate of filtration. Coagulant used will be syrup of alum manufactured at the plant.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*)

New York's Experience with Copper Sulphate. FRANK E. HALE. Pub. Works, **57**: 221-23, 1926. Copper Sulphate treatment of several of New York's large reservoirs for tastes caused by Asterionella, Dinobryon, Synedra, and Synura are described. The copper sulphate was distributed by boats, the dosage varying from 0.18 to 0.36 p.p.m. Procedure for treating and putting a reservoir back into service is outlined.—*C. C. Ruchhoft* (*Courtesy Chem. Absts.*).

Iron and Manganese Troubles. W. F. MONFORT. Engr. & Contr., **65**: 169-72, 1926. Red water troubles with pitting and deposits in water pipes caused by iron and manganese in quantities of from 0.1 to 5 p.p.m. in conjunction with Crenothrix are discussed. Iron and manganese may be eliminated by an iron removal plant with chlorination to destroy the Crenothrix. Troubles from red water caused by corrosion may be solved by pH control with lime.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

The Quality Problem in Relation to Chicago's Water Supply. JOHN ERICSON. Engr. & Contr., **65**: 173-4, 1926. Chicago water supply is becoming more potentially dangerous due to the occasional reversal of the Chicago River, the frequent discharge of the Calumet River into the lake, and the sewage and industrial wastes dumped into the lake by the growing communities situated around southern end of Lake Michigan. Increasing quantities of chlorine required for disinfection are rendering the supply objectionable for drinking purposes. Filtration is recommended and plans for filtration plants are outlined.—*C. C. Ruchhoft* (*Courtesy Chem. Absts.*).

Maintenance Service for Fifty Municipalities. Anon. Pub. Works, **57**: 157-61, 1926. Meter testing and repair department operated by Hackensack Water Company in maintaining nearly 60,000 services is described.—*C. C. Ruchhoft.*

Architectural Treatment in Water Engineering. J. HUSBAND. Pub. Works, **57**: 161-63, 1926. Desirability of effectual architectural treatment for dams, gate towers, and other structures is discussed and examples from British and American practice are cited.—*C. C. Ruchhoft.*

Water Works Statistics for 1925. Anon. Pub. Works, **57**: 181-90, 1926. Data for 1925 obtained from nearly 400 cities of all sizes and geographical districts in the United States on amounts of mains laid, percentages of services metered, features of meter rates, and chemicals used in purifying water are tabulated.—*C. C. Ruchhoft.*

The Improvement of the Water Supply of Keene, N. H. R. S. WESTON and G. A. SAMPSON. Jour. New Eng. Water Works Assoc., **40**: 1, 1, March, 1926. Pressure and volume of water for fire hydrant service increased by cleaning the

pipes and building 1.5 m.g. storage reservoir on Beech Hill. Investigations indicated that epidemic of gastro-enteritis in October 1923 may have been due to accidental contamination of Roaring Brook and Echo Lake, the sources of supply. Slow sand filters have been built at Beech Hill and Stone Dam with capacities of 0.75 and 1.5 m.g.d. respectively. At Central Square available water at 60 pounds pressure was raised from 1,500 to 4,000 gallons per minute. Treatment by chlorine or rapid sand filters deemed inadvisable due to high color of the water and sudden changes in quality. Discussion follows. —*W. U. Gallaher.*

The Economy of Municipal Bonds for Water Works Construction. C. W. Sherman. Jour. New Eng. Water Works Assoc., **40**: 1, 16, March, 1926. Provided bonded indebtedness of municpality is kept low enough to insure good credit, it is better to issue bonds rather than raise money by special assessments in order to pay for improvements. Municipality can borrow money at 4 per cent, whereas citizens must pay 6 per cent.—*W. U. Gallaher.*

Effect of Deciduous and Coniferous Forests on Rainfall and Run-Off. J. W. Toumey. Jour. New Eng. Water Works Assoc., **40**: 1, 40, March, 1926. Forests have no effect on total precipitation. They may take up as high as 50 per cent of rainfall for their own use but they make the soil more porous than that in treeless regions. Water is therefore distributed in the streams over a long period and also clarified. Coniferous trees are best for a watershed since they take only 10 to 20 per cent as much water for their own use as deciduous trees.—*W. U. Gallaher.*

Financing Main Pipe Extensions by the Assessment Method. G. A. Elliott. Jour. New Eng. Water Works Assoc., **40**: 1, 22, March, 1926. See same Journal, **39**: 3, 185, Sept. 1925. Spring Valley Water Company stands expense of laying mains if cost does not exceed four times estimated yearly revenue. If cost is greater, applicant must deposit excess with Company, to be refunded as revenue increases. The San José Water Works installs mains at their own expense up to 100 feet per consumer. Cost in excess of this must be deposited with Company and for each consumer subsequently added to line, refund is made to initial depositors equal to cost of 100 feet of mains. In new subdivisions, estimated cost plus 10 per cent for overhead must be advanced by applicant. If within 7 years, annual revenue from water equals 25 per cent of total cost, deposit is refunded.—*W. U. Gallaher.*

Report of the Metropolitan Water Supply Investigating Commission. Jour. New Eng. Water Works Assoc., **40**: 1, 61, March, 1926. Present sources of supply can furnish average of 119 m.g.d., while consumption is 130 m.g.d. City of Worcester uses 130 m.g.d. from its own supply and buys an additional 5-6 m.g.d. from the Metropolitan District. Purification of South Sudbury system at initial expense of $3,500,000 would add 26 m.g.d. Damming of the Ware and Swift Rivers would, together with South Sudbury system, give a supply to the Metropolitan District and Worcester that should be ample for 75 years, and at as low a cost per million gallons as any. Investment, how-

ever, would be large and full utilization somewhat problematical. Communities in affected districts would object and water to be used by Worcester would have to be elevated several hundred feet. Damming of the Ware at Barre Falls at cost of $14,000,000 would give reservoir with capacity of 45 m.g.d. whence water would flow by gravity either to Worcester system or to Wachusett Reservoir; a compensating reservoir of 11 billion gallons capacity being built below to furnish water for industrial purposes, water being preferred by riparian owners to cash settlement. By directing certain branches of upper Assabet River into Wachusett aqueduct at cost of $8,500,000, 47 m.g.d. would be available. Eighty m.g.d. of which 50 could be pumped to Metropolitan System, can be secured from Ipswich River above town of Topsfield at cost of $19,000,000. Hobbs Brook Reservoir of Cambridge may be increased by 30 m.g.d. by raising present dam 30 feet at cost of $12,000,000. Total additional supply from North Ware, Assabet, Ipswich, and Hobbs Brook would be 202 m.g.d. at total cost of $53,000,000. Waters from last three would require filtration, and that of North Ware when mixed with the present Wachusett water would lower quality of latter. Quinebang River available, but very remote. Desirable to construct deep pressure tunnel in underlying rock between Weston terminal and City of Everett at probable cost of $17,000,000. Commission makes following recommendations: (1) Creation of special construction commission with authority to improve and increase present water supply; (2) Construction of filtration plant to treat South Sudbury supply; (3) Construction of reservoir on upper Ware River; (4) City of Worcester to take one-ninth of water from new reservoir, paying one-ninth of costs of construction and maintentance, and, as its consumption increases, additional water in increments of one-ninth, paying one-ninth of original cost and yearly maintenance; (5) Purchase of site for filtration plant for waters of Weston aqueduct; (6) Procuring of land within the watersheds of Assabet and Ipswich Rivers to protect sanitary quality of their waters and prevent encroachment by private parties; (7) Commission to study and report on means of delivery of water to Metropolitan District; (8) An appropriation of $27,500,000 by the Legislature.—*W. U. Gallaher.*

The Massachusetts Water Report. Allen Hazen. Jour. New Eng. Water Work Assoc., 40: 1, 44, March, 1926. Review of report of Metropolitan Water Supply Investigating Commission. Followed by discussion by Col. Charles R. Gow, member of the Commission.—*W. U. Gallaher.*

Cement-Lined Cast-Iron Pipe. C. W. Sherman. Jour. New Eng. Water Works Assoc., 40: 1, 98, March, 1926. Pipe lined by insertion of liquid cement to the inside and then rotating with peripheral speed increasing from 300 feet per minute at the start to 600 feet per minute at the finish. Cement to sand ratio, 3:1; thickness of coating, $\frac{1}{16}$ to $\frac{3}{16}$ inch, depending on size of pipe. Cost (for long pipes) varies from 5 cents per foot for 4-inch to 35 cents per foot for 24-inch pipe. Appendix I. Specifications for cement-lined cast-iron pipe and fittings. Appendix II. J. E. Gibson. Determinations of the coefficient "C" in Hazen and William's formula for Cement-Lined Cast-Iron Pipe. Value of 144.5 thought nearest correct.—*W. U. Gallaher.*

Middle Rio Grande Conservancy Project Under Way. Eng. News-Rec., **96**: 522, April 1, 1926. Outline of irrigation and drainage project of Middle Rio Grande Conservancy District, New Mexico, which will involve straightening of river course, construction of one or more dams for retaining 200,000 acre-feet, and levees for flood protection.—*R. E. Thompson.*

Additional Water Supply Under Way for Kansas City, Mo. Eng. News-Rec., **96**: 492–4, March 25, 1926. Description of new plant which will supply 100 (average) to 125 m.g.d. of purified Missouri River water to Kansas City, Mo., increasing present supply by about 50 per cent. Works consist of mass concrete crib of 150 m.g.d. capacity, protected by standard fascine mattress and rock paving; four 38-inch welded steel suction pipes, 150 feet long, to the 140-m.g.d. low-lift pumping station; four 4-m.g.d. preliminary settling tanks equipped with revolving clarifiers, estimated to reduce suspended matter 90 per cent; two 1-m.g.d. mixing tanks where alum and lime are applied, provision being made for secondary application in final settling tanks; 3 coagulation basins of 372 m.g. total capacity, with facilities for continuous sludge removal; 2 final settling basins of 14½ m.g.d. total capacity; twenty-four 4-m.g.d. filter units, sand and gravel depths in which are 27 and 18 inches respective two 75,000-gallon steel wash-water tanks and a third of a similar dapacity for general purposes; and 600-pound per day chlorinating apparatus. Provision has been made for manufacture of alum at the plant. Extensions also include two pure water tunnels, conduit and 17-m.g. covered equalizing reservoir.—*R. E. Thompson.*

Simple Connection to Steel Mains. F. Johnstone-Taylor. Eng. News-Rec., **96**: 583, April 8, 1926. Brief illustrated description of system devised for making small connections to steel pipe.—*R. E. Thompson.*

San Francisco Bay Crossing of Hetch Hetchy Aqueduct. Eng. News-Rec., **96**: 434–8, March 18, 1926. Bay Crossing Division of Hetch Hetchy project is being constructed now, 7 years before it can be used to convey Hetch Hetchy water, to supplement pipe lines carrying water from East Bay sources of Spring Valley Water Co. As a whole, the Bay Division now being completed is 21 miles in length and, except for Pulgas tunnel (8675 feet long) and submarine pipe in Bay (2750 feet) and across Newark slough (400 feet), consists of 60-inch pipe of 45-m.g.d. capacity buried in trench or laid on trestle. The Bay Crossing proper, described in present article, includes 3870 feet of steel bridge on west side of Bay terminating in thrust pier, and flexible 42-inch pipe laid on Bay bottom between pier and east shore. Bridge, which was designed for two 76-inch lines in ultimate development, is now carrying one 60-inch line, and overall cost of bridge, pier, and pipe was $400 per foot of bridge. Construction of bridge and laying of pipe described in some detail. First 234 feet of submerged pipe was laid from temporary trestle, rendering it possible to pour lead joints above water and lower pipe after considerable length had been completed. Maximum time required for calking joint, which required 400 pounds of lead, was 45 minutes.—*R. E. Thompson.*

Reconstructing the Calaveras Dam by Dry Fill. G. A. Elliott. Eng. News-Rec., **96**: 514–7, April 1, 1926. Reconstruction of Calaveras dam by Spring Valley Water Company described and illustrated. Finished structure is earth and rock dam with rolled clay core, 220 feet above bedrock, with volume of 3,461,000 cubic yards, creating reservoir with capacity of 32,800 m.g. Spillway is lined with reinforced concrete and is 1450 feet in length. Construction of lower half by hydraulic fill was interrupted by slipping of 800,000 cubic yards of embankment into reservoir. Since that time upper portion has been completed by rolled clay core supported by uncompacted soft rock banks dumped into place.—*R. E. Thompson.*

Piling and Wire Fencing Protect Stream Bank Near Bridges. Eng. News Rec., **96**: 419, March 11, 1926. Brief illustrated description of method of protecting stream banks employed by California State Highway Commission, consisting of driving double line of piling, on which heavy barbed wire is fastened at 6-inch spacing, and planting willows between bank and these jetties.—*R. E. Thompson.*

Federal Interest in Flood Control. Riley J. Wilson. Eng. News-Rec., **96**: 411, March 11, 1926. Progress under 1917 Act of Congress reviewed briefly.—*R. E. Thompson.*

Value of Flood Control. C. A. Book. Eng. News-Rec., **96**: 411, March 11, 1926. Brief general discussion.—*R. E. Thompson.*

Flood Protection for Freeport, Ill. W. G. Potter. Eng. News-Rec., **96**: 411, March 11, 1926. Relief project provides for 2-2½-mile diversion channel around city for Pecatonica River at cost of $660,000–780,000. In 10½-year record of flow, average for 119 days was less than 500 second-feet while on 4 days during that number of years discharge was 14,000 second-feet. Highest on record is 17,000, in 1916, when estimated damage was $100,000.—*R. E. Thompson.*

Progress on the Experimental Arch Dam. Eng. News-Rec., **96**: 494–5, March 25, 1926. Excavation for the experimental dam being built by Engineering Foundation was completed and all materials required for construction were at site in February. Three main values will be measured: deflection, deformation, or strain, and temperature, employing at least two independent methods in each case. Methods of measurement which will be employed are outlined.—*R. E. Thompson.*

Welded Swimming-Pool Tank in a Chicago Club Building. Eng. News-Rec., **96**: 366–7, March 4, 1926. Brief illustrated description of electrically-welded steel swimming pool, 60 by 30 feet, with glazed tile lining, on sixth floor of Standard Club Building, Chicago.—*R. E. Thompson.*

Eleven Dams Make Storage Reservoir of Lake Kenogami. A. F. Dyer. Eng News-Rec., **96**: 404–8, March 11, 1926. Illustrated description of con-

struction of structures which will convert Lake Kenogami into 15,000,000,000-cubic foot storage reservoir and provide minimum continuous flow of 1800 second-feet throughout year for power purposes. Largest structure is concrete dam across Chicoutimi River, which is 1500 feet in length and 80 feet (maximum) in height. Details are included of method employed in placing concrete on this dam, which was carried out when temperature was usually below zero. Retaining works on Ausable River are situated where river is divided by an island and consists of 4 separate structures—2 dams and 2 bulkheads. Other structures are small concrete dams and dikes. Total cost of undertaking, including compensation for flooded lands, will be nearly $4,000,000.—*R. E. Thompson.*

Methods Used in Testing Yields of Water Works Wells. G. C. Habermeyer and C. V. Swearingen. Eng. News-Rec., 96: 414, March 11, 1926. Description of methods employed for measuring depth of water and yield of wells.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

The South Canadian River. A. S. Stinnett. Eng. News-Rec., 96: 411, March 11, 1926. Reconnaissance surveys have been carried out in connection with flood control on South Canadian River and sites have been located for 3 dams which will be over 100 feet high, each creating storage capacity of 500,000 acre-feet.—*R. E. Thompson.*

Single Building Houses Bismarck's New Pumps and Filters. Thorn Dickinson. Eng. News-Rec., 96: 371–3, March 4, 1926. New plant at Bismarck, N. D., for purifying and softening Missouri River water, consists of Diesel engine, generator, high- and low-lift pumps, mixing chambers, three 0.75-m.g.d. filters, chemical feed machines, chlorinator, and laboratory, all under one roof. Latter arrangement has not given rise to any trouble due to moisture. Feature of works is provision for use of domestic-service high-lift pumps as fire pumps at increased pressure, supply being derived from high-level storage reservoirs formerly used as sedimentation basins, affording fire flow triple capacity of filtration plant. Plant is part of additions to privately owned works acquired by city in 1923. Cost of old system was $273,000 and of new work $397,000, including extensive additions to distribution system.—*R. E. Thompson.*

Concrete Arch Dam with Central Spillway Built on Klamath Project. A. L. Darr. Eng. News-Rec., 96: 331, February 25, 1926. Brief details given of Gerber Dam in Oregon, completed last June by United States Bureau of Reclamation. Dam is of concrete and of pure arch type, 478 feet long on top and 75 feet high from foundation to crest of spillway. Central portion for length of 150 feet is shaped as overfall dam to serve as spillway. Thermometers built into concrete and gage-point stations were provided for future observations.—*R. E. Thompson.*

Exchequer Dam Closure to be Made by Timber-and-Concrete Gates. Eng. News-Rec., 96: 418, March 11, 1926. Brief illustrated description of gates

for two openings through which Merced River was passed during construction of Exchequer Dam. Gates are each 16 feet wide by 30 feet high and consist of backing of 12- by 30-inch timbers laid flat and faced with reinforced concrete slab 18 inches thick, extending full height of gate.—*R. E. Thompson.*

Recent Rock Tunneling Methods, Illinois Central R. R. Eng. News-Rec., 96: 370, March 4, 1926. Brief outline of methods employed in construction of 3 tunnels through Ozark Hills, 800, 6900, and 2600 feet in length respectively.—*R. E. Thompson.*

Timber Dapping Machine Used on Moffat Tunnel. Eng. News-Rec., 96: 333, February 25, 1926. In framing tunnel timbers, cutting of daps by hand is an expensive item. Dapping machine, designed by C. A. Betts, is described which has saved many times its cost in few months of steady work during construction of Moffat Tunnel. Cost was $600, including motor.—*R. E. Thompson.*

High Overflow Dam Main Unit of Baker Power Plant. Eng. News-Rec., 96: 360–2, March 4, 1926. Illustrated description of plant of Puget Sound Light and Power Company in canyon of Baker River. Dam, which is of concrete, is curved on radius of 250 feet and has crest length of 493 feet and total height of 263 feet from bedrock to top of gate piers. At greatest depth, total width of cross-section, including apron, is 180 feet. Dam is of overpour type, with spillway control by means of gates on crest.—*R. E. Thompson.*

Sennar Dam on the Blue Nile in Egypt Completed. Eng. News-Rec., 96: 316–7, February 25, 1926. Illustrated description of irrigation system which consists of dam and 775 miles of canals. Cost of entire project was approximately $43,000,000. Dam is 9925 feet long, made up of central portion of rubble masonry, of gravity section, and two end portions constructed partially of masonry and partially of earth fill. Height from channel bottom to spillway section is 68 feet and maximum overall height is 130 feet.—*R. E. Thompson.*

Huge Reservoir and Pumping Plant for London (Eng.) Water Supply. Eng. News-Rec., 96: 200–1, February 4, 1926. Brief illustrated description of Queen Mary reservoir and of its new 300- to 412-U.S.m.g.d. pumping plant consisting of centrifugal pumps and uniflow steam engines. Reservoir covers area of 723 acres and water depth when full is 38 feet, capacity being nearly 8 billion U. S. gallons. Embankment is of earth with clay puddle heart-wall, lower section of water slope being paved with 6-inch concrete slabs and higher section with concrete blocks. Earth baffle embankment 4000 feet long was constructed nearly across width of reservoir between inlet and outlet, which are on opposite sides, to promote circulation.—*R. E. Thompson.*

Tests of Water Pressures Under Brule River Dam. Eng. News-Rec., 96: 274–5, February 18, 1926. Brief data given on pressure measurements under dam made by means of pipes from cups in foundation to downstream face

which were placed during construction. Four of seven pipes showed no pressure, and maximum pressure recorded was only 50 per cent of that which would be due to head of water.—*R. E. Thompson*

Will Hole Through Moffat Tunnel in July, 1926. C. A. Betts. Eng. News-Rec., 96: 284–5, February, 18, 1926. Brief data given on progress in construction of Moffat Tunnel in Colorado, 66 per cent of which has been completed. Eighty per cent of water tunnel has been finished to date. Notes on construction included.—*R. E. Thompson.*

Water Charge for Construction Uses. Eng. News-Rec., 96: 289, February 18, 1926. City of Mobile, Ala., imposes charge of 6 cents per cubic yard of concrete and 12½ cents per 1000 brick for water used by construction companies from city mains. Lowering of charges is being considered.—*R. E. Thompson.*

Tests of Cement-Asbestos Pipe. W. S. Pardoe. Eng. News-Rec., 96: 169, January 28, 1926. Results are given of tests of 150-mm. (5.9 inch) inside diameter pipe 15-mm. (0.59 inch) in thickness, constructed of 85 per cent slow-setting portland cement and 15 per cent asbestos fibre. Bursting pressure varied from 300 to 450 pounds per square inch, corresponding to tensile stresses of 1500-2250 pounds per square inch. Joint, which consists of sleeve, 2 rubber rings about ⅜-inch square and 2 cast-iron collars pulled gether by three ⅜-inch bolts in form of double stuffing box, showed no leakage prior to bursting, which occurred at remote point, indicating that joint was stronger than pipe. Interior of pipe is as smooth as marble and discharge capacity is 15 per cent greater than clean cast-iron and 45 per cent more than slightly tuberculated cast-iron pipe. Pipe is not subject to tuberculation and hence maintains discharge capacity and is non-con. ductor and therefore not subject to electrolysis. Material can be cut with hack saw, machined in lathe, drilled and tapped for corporation cocks. Weight is about ⅓ that of cast-iron pipe for same service and cost is less. Pipe is manufactured in Genoa, Italy, on cylinder pipe machine by building up layers of cement asbestos about 0.2 mm. in thickness on mandrel under pressure.—*R. E. Thompson.*

Leakage Test of 36-Inch Concrete Sewage Force Main, Dallas, Texas. E. A. Kingsley. Eng. News-Rec., 96: 294, February 18, 1926. Brief details given of reinforced-concrete force main which on 14-day contract test showed leakage averaging 117 gallons per inch per mile in 24 hours compared with contract requirement of 200 gallons. Line is 36 inches in diameter and has total length of 14,250 feet, difference in level between pump and outlet end being 34.5 feet. It is composed of precast pipe in 12-foot lengths, and except for 2 or 3 joints in wet locations jointing material throughout was of neat cement, about consistency of putty, calked against jute. Thickness of walls is 4½ inches. Pipe is patented and is known as "Trammell system copper bell concrete pressure pipe."—*R. E. Thompson.*

Construction of Steel Portion of Providence Aqueduct. BAYARD F. SNOW. Eng. News-Rec., 96: 159–61, January 28, 1926. Illustrated details given of construction of steel portion of aqueduct from new source of supply of Providence, the Scituate reservoir. Aqueduct consists of over 3 miles of concrete-lined tunnel through rock, somewhat over 1 mile open-cut reinforced concrete lined, and nearly 2 miles of riveted steel pipe, 8300 feet of which is 66 inches in diameter and remainder 48 inches. After removal of all rust and loose scale pipe was coated first with cold "bitumastic solution" and then with hot "bitumastic enamel." Backfilling was carried out with great care to avoid damaging coating. Failure to remove drop-hole plug while draining first section after testing resulted in buckling at top of 200 feet of 66 inch pipe. By means of water pressure up to 35 pounds and 35- and 50-ton jacks, pipe was brought back to almost correct shape. It is believed that by employment of water pressure of 100 pounds, together with pneumatic hammer to set up vibrations, reshaping of pipe could have been carried out more economically. Pipe consisted of rolled $\frac{5}{16}$-inch plate conforming to A.S.T.M. serial designation A7-21.—*R. E. Thompson.*

New York State Prohibits Cross-Connections. Eng. News-Rec., 96: 161, January 28, 1926. Cross-connections between potable water supply systems and any other system in New York State are prohibited by regulation adopted November 12, 1925, unless other supply is regularly examined by those in charge of potable supply and found to be of satisfactory quality. All existing connections must be severed by July 1, 1926, unless they "include two gate valves with indicator posts, two check valves of Special Factory Mutual Fire Insurance design or equipped with drip cocks and gages for testing, all located in vault of watertight construction accessible for ready inspection," in which case time is extended to July 1, 1928.—*R. E. Thompson.*

Existing Practices of Polluting Public Water Courses. GEO. W. FIELD. Science, 63: 443–6, April 30, 1926. General discussion of pollution of water courses in which it is pointed out that practice of discharging waste oil into bodies of water, producing film which rapidly spreads over an ever-increasing area, curtails exchange of gases between atmosphere and water, thus depriving water of oxygen necessary for life processes of microörganisms and for oxidation of polluting organic matter.—*R. E. Thompson.*

1925 Drought Breaks All Records in Southern Appalachians. E. D. BURCHARD. Eng. News-Rec., 96: 234–5, February 11, 1926. Data on rainfall and stream flow during year ending September 30, 1925, given. Average deficiency of rainfall at 12 selected stations was 37 per cent for year and 49 per cent for period February–September. At 28 of 30 selected stream gaging stations minimum flow was lower during 1925 than any previously recorded. —*R. E. Thompson.*

New Willow Bank Protection Tried Out By California Highway Department. Eng. News-Rec., 96: 165–6, January 28, 1926. Departure from usual type of willow protection work described briefly. Cuttings not exceeding 1 inch in

diameter were planted with small ends pointing upstream, and timber boxes 1 x 4 x 10 feet, constructed of 2-inch material, were filled with gravel and anchored on top of mat at 45-degree angle to flow of stream and 15-20-degree angle to water surface. Resulting deposit of silt on young trees materially aided their growth. Cost of boxes installed averaged $9.88 each.—*R. E. Thompson.*

Flow Tests of Old Cast-Iron Water Mains, Chicago Water Works. J. B. Eddy. Eng. News-Rec., 96: 287, February 18, 1926. Brief data given on results of examinations of water mains in Chicago, some of which have been more than 50 years in service. About 400 taps, 3 to 12 inches in diameter, are made yearly for inspection purposes. Age has little or no effect on carrying capacity in Chicago, and it is therefore customary in estimating size of feeder mains to assume that pipe coefficient will not change.—*R. E. Thompson.*

Volcanic Formations Govern Design in Pit River 3 Hydro Development. Walter Dreyer. Eng. News-Rec., 96: 144–9, January 28, 1926. Illustrated description of recently completed Pit River 3 development of Pacific Gas and Electric Company, including diversion dam and pressure tunnel. Dam is of ogee spillway type, arched in plan on 500-foot radius, and is 112 feet in height from foundation to crest. Foundation was such that grouted cutoff wall was necessary. Baffle piers were constructed in apron to prevent erosion and scour below dam, hydraulic jump method not being adapted to site. Tunnel is 21,230 feet long, concrete-lined and circular in section, and has inside finished diameter of 19 feet.—*R. E. Thompson.*

Fargo, N. D. Eng. News-Rec., 96: 152–3, January 28, 1926. Brief details given of water supply of Fargo, which is obtained from Red River. Turbidity of raw water varies between 15 and 350 p.p.m. Water is sold at 15 cents per 1000 gallons, average cost being 11.5, distributed as follows: pumping 5.64, filtration 3.06, mains and hydants 1.25, meters 0.8, depreciation 0.96. Since filtration plant was installed in 1912, only 3 deaths from typhoid have occurred, and origin of these cases was obscure. Population is about 25,500. —*R. E. Thompson.*

Water Works and Sewerage Systems in Middle West Cities. Eng. News-Rec., 96: 153, January 28, 1926. Table given, based on information collected by Geo. W. Putnam, showing number of cities in Iowa, Kansas, Missouri, and Illinois which have water and sewer systems, classified in 3 groups according to population, namely, above 2500, 1000–2000, and below 1000.—*R. E. Thompson.*

Economic Design of Pipe Lines. J. W. Ledoux. Eng. News-Rec., 96: February 11, 1926. Formulas given for use in economic design of gravity and pumping mains.—*R. E. Thompson.*

Retention and Excretion of Lead. A. S. MINOT and J. C. AUB. J. Pharmacol., **23**: Proc. 159, 1924. From Chem. Abst., **18**: 3230, October 20, 1924. In chronic lead poisoning the lead is retained indefinitely in solid portion of bones. Such immobilized lead is harmless but is held at point where its liberation would flood the organism with toxic soluble lead. Depleted alkali reserve tends to mobilize stored lead. Whether this increased acidity is produced artificially by acid ingestion or by pathological conditions, mobilization and excretion of lead are temporarily increased. Negative calcium alone decreases stability of deposit and when this condition is combined with simultaneously increased acidity lead excretion is more markedly increased.—*R. E. Thompson.*

Super-Cements. OTTO GRAF. Z. Ver. deut. Ing., **68**: 853-6, 1924. From Chem. Abst., **18**: 3264, October 20, 1924. Portland and other high-grade cements are compared from standpoint of construction engineer. In general super-cements are preferred for greater strength, early high strength, resistance to chemical action, and low shrinkage. They are less desirable for their low elasticity, dark shade, and high cost. They are similar to portland cement in regard to effect of water cement ratio in mix and also as regards time of set.—*R. E. Thompson.*

Fused Cement. NITZSCHE. Zement, **13**: 136-7, 1924. From Chem. Abst., **18**: 3264, October 20, 1924. Action of 7.5 per cent magnesium sulfate solution on fused cement briquets was very slight during 12-month period. At 90 days tensile strength of 34.7 kgm. per square centimeter and crushing strength of 702 kgm. per square centimeter were attained. On longer immersions former increased while latter decreased slightly. Contraction of specimens of both neat fused cement and of 1:3 mixes with sand in 2.4 per cent magnesium sulfate solution, allowance being made for intermittent immersions and drying periods, was same as that of check pieces in tap water. —*R. E. Thompson.*

Forty-third Annual Report of the Provincial Board of Health, Ontario, Canada for the Year 1924. 149 pp. **Annual Report, Division of Sanitary Engineering.** F. A. DALLYN. Ibid., 99-106. Progress in sanitation in the province is reviewed. Prior to 1913 there were 7 water purification systems in operation, while at present there are 41 purification plants and 96 chlorinating installations. The typhoid death rate for the towns and cities during 1924 was 2.5 per 100,000, the lowest in the history of the province. In 1910 the rate was 31.5. **Activities of the Experimental Station for 1924.** A. V. DELAPORTE. Ibid., 112-4. Researches carried out and in progress are outlined. Laboratory experiments on coagulation with Na aluminate were fairly successful, but few waters were found which were sufficiently acid to precipitate completely the amount required for efficient filtration. It was found that when certain strength solutions of alum and Na_2CO_3 were mixed, the first precipitate of $Al(OH)_3$ redissolved, and that when the resulting solution was added to water an $Al(OH)_3$ floc was obtained immediately. Laboratory experiments on coagulation of a number of different types of water by this method

have given excellent results, and it is proposed to apply it on a practical scale. If successful, the advantages of this treatment for waters of low alkalinity are obvious. **Report of Field Work re Fire Underwriters' Cross-Connections.** G. A. H. Burn. Ibid., 118–32. Data obtained in survey of private fire supplies is tabulated and discussed. One of the checks was leaking in 16 of the 71 dual check installations tested at 46 plants. **Motor Tourist Camps.** A. V. Delaporte. Ibid., 133–149. Town water supplies were available in 60 of the 127 camps inspected in survey carried out in 1924; wells were employed in 56; springs in 9; rivers and lakes in 7; and in 4, there was no provision for water supply. Fifty-four of the well, spring, river, and lake supplies showed considerable contamination, 16 were fair, and 9 were in good condition.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Effect of Manipulation on Strength of Field Concrete. G. W. Hutchinson. Eng. News-Rec., 96: 246-7, 1926. Discussion of effect of manipulation on strength of concrete, in which brief comparative data is given on strength of edge and middle concrete of 27 different highway projects. There was only 3 per cent variation between average strength of edge cores and those from center, but the mean deviation from average in former was 20 per cent and but 5 per cent in latter. Most important factor is therefore workability, as by building this property into mass, it can be flowed into place with minimum of manipulation.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

How to Prevent and to Restore Frozen Concrete. A. M. Bouillon. Eng. News-Rec., 96: 408-10, 1926. Methods of preventing freezing of concrete and of thawing and curing frozen concrete are described. Concrete which has been frozen may be restored to very near, or possibly to full efficiency, provided it has not been exposed to repeated freezing and thawing. Loss in strength after a second freezing may be 20–30 per cent and after fourth exposure 50-70 per cent. Investigations indicated that while wet concrete expands more than a dry mixture on freezing, less injury results to former when thawed and allowed to set properly, owing probably to greater plasticity which enables normal condition to be regained, and to unimportance of additional loss of moisture, which has marked influence on strength of dry mixture.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Records on a Concrete Road Using Weighed Aggregates. W. E. Barker. Eng. News-Rec., 96: 440-1, 1926. Method of proportioning aggregates by weight employed in road construction in Iowa is described. Tests showed that this method gave more uniform concrete and lower percentage of cement used in excess of the theoretical than volume measurement. Labor required is the same for both methods.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Studies of Curing Concrete in a Semi-Arid Climate. C. L. McKesson. Eng. News-Rec., 96: 452–3, 1926. Paving concrete cured with $CaCl_2$ (2½ pounds per square yard) was found to be 80–90 per cent efficient in 90 days and practically 100 per cent in 1 year compared with water-cured concrete. Experiments employing varying periods of watering showed that the first

3 days is the critical period and that if sufficient water is supplied during this period, hydration will proceed for at least 90 days. Maximum strength at 90 days was obtained with 7 days' watering, there being no appreciable gain up to 14 days. Sections cured by simply covering with dry earth showed good strength at 14 days but there was no material gain up to 90 days. The surface of the unwatered sections was much softer than that of the other sections, the surface hardness of which was satisfactory regardless of period of watering.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Stream Pollution by Acid Mine Drainage. R. D. Leitch. U. S. Bur. Mines Rept. of Investigations, **2725**, 7 pp., January, 1926. More than 150 supplies in United States and Canada affected by acid mine drainage. More then 9,000,000 tons of sulphuric acid annually dumped into streams of Pennsylvania alone. Damage from this source includes $1600 annually for each locomotive and $50,000 annually to locks and dams in Pittsburgh district, $10 annually to plumbing in each residence in Pittsburgh, aggregating $3,000,000, and more in industrial plants, and destruction of fish for 263 miles below city. Mining increases penetration of surface water and about 27 per cent of rainfall is pumped from mines as acid water. Only about 6 per cent of area underlain by coal in Pittsburgh district has been mined and, since worked-out mines continue to produce acid water as though still active, problem will become greater. In few cases attempt made to neutralize acid with limestone, lime, or marl. At one mine iron oxide recovered and sold. Use of barium chloride suggested, but so far, too costly. To purify present acid waters in Pennsylvania would cost $10,000,000 for installation, and $225,000 annually for lime for neutralization besides $750,000 for subsequent necessary softening. Sanitary Water Board of Pennsylvania has grouped streams of State into those so badly polluted that improvement is impracticable or impossible, those that are polluted but can be restored, and those as yet unpolluted. No control to be attempted in first class, purification to be required in second class, and dumping of wastes to be prohibited in third class.—*David G. Thompson.*

Boiler Water Conditioning with Special Reference to High Operating Pressure and Corrosion. R. E. Hall. U. S. Bur. Mines Repts. of Investigations, **2727**, January, 1926. Discusses factors to be considered in treatment of boiler waters to prevent formation of scale and corrosion not merely on evaporating surfaces of boilers but also in feed water lines, preheating sections, and parts of systems in which steam is used. Considers use of soda ash and sodium phosphate and relation between chemical used and operating presssure to obtain best results.—*David G. Thompson.*

Sixth Biennial Report of State Engineer and Surface Water Supply of New Mexico (for years 1923 and 1924), 214 pp., 1925. Contains draft of proposed compact between New Mexico and Texas relating to utilization of water from Pecos River, short report on quantity of ground water available for irrigation in Estancia Valley, and stream flow data for New Mexico streams for 1923 and 1924.—*David G. Thompson.*

Comparison of Chemical and Bacteriological Examination Made on the Illinois River During a Season of Low and a Season of High Water, 1923-1924. R. E. Greenfield. Ill. State Water Survey Bull. **20**: pp. 9–33, 1925. Gives results of determinations of dissolved oxygen and biological demand and bacteriological tests along 35-mile stretch of Illinois River during periods of unusually low flow in 1923 and high flow in 1924. In 1923 pollution so great in upper section of river that no dissolved oxygen was found as far down as Chillicothe, 146 miles from Lake Michigan, and existence of fish was impossible. Below Chillicothe oxygen increased to maximum at Peoria Narrows. Wastes from Peoria and Pekin increased pollution but not to degree prevalent farther upstream. In 1924 condition of water was much better than in 1923, due to greater dilution, but major variations seem to have been caused by material carried in by freshets rather than by introduced pollution.—*David G. Thompson.*

A Preliminary Notice of a Survey of the Sources of Pollution of the Streams of Illinois. G. A. Weinhold, R. E. Greenfield, A. M. Buswell. Ill. State Water Survey Bull. **20**: pp. 34–59. 1925. Communities in State having sewerage systems listed according to type in use and each described briefly; 136 systems dumping unpurified sewage into streams, 72 treating in some sort of sedimentation tank, 57 treating with some device in addition to sedimentation. Distribution of systems shown on three maps. Sources of pollution in Iroquois and Kankakee counties, including pollution by industries according to character, shown on separate map.—*David G. Thompson.*

Precipitation in the Drainage Area of the Great Lakes, 1875-1924, with a Discussion of the Levels of the Separate Lakes and Their Relation to the Annual Precipitation. P. C. Day, Monthly Weather Review, **54**: 3, 85-106, March, 1926. Gives precipitation data for Great Lakes region and compares fluctuations in lake levels with changes in precipitation. Graphs show that lake levels change approximately in accord with precipitation with lags on the different lakes ranging from a few months to a year.—*David G. Thompson.*

Record of Dry Spells at Nashville, Tenn., 1871-1925. Roscoe Nunn. Monthly Weather Review, **53**: 9, 398, September, 1925. In 55 years a total of 69 dry spells of 21 days or longer in which precipitation was less than 0.25 inch. Longest spell was 43 days. Four spells of 40 days or more and 16 spells of 30 days or more. Average number of dry spells per year was 1.3.—*David G. Thompson.*

Wide Area Forecasting of Stream-Flow on the Columbia and Colorado. J. E. Church. Monthly Weather Review, **53**: 8, 353–354, August, 1925. Despite large areas of drainage basins, conditions are such that it is believed a few well placed snow survey stations will give reliable forecasts of water supply available for irrigation and industrial needs.—*David G. Thompson.*

Seasonal Precipitation in California and Its Variability. B. M. Varney. Monthly Weather Review, **53**: 4 and 5, 148–163 and 208–218, April and May,

1925. Critical analysis of California precipitation data with special attention to seasonal departures from average seasonal rainfall, frequencies of rainfall of certain amounts, and mean seasonal variability of precipitation. Seasonal variability is defined as the difference between successive seasonal totals of precipitation regardless of sign. It becomes significant when studied with mean departure from normal in considering reservoir capacities required to cover periods of deficiency. A new rainfall map of California, based on records adjusted to a uniform period of 25 seasons accompanies the paper.—*David G. Thompson.*

A Preliminary Study of Effective Rainfall. J. F. Voorhees. Monthly Weather Review, 53: 2, 63–65. February, 1925. Considers disposal of rainfall in Knoxville, Tenn., region. Gives data on interception of rainfall by vegetation and on lysimeter experiment at University of Tennessee Experiment Station.—*David G. Thompson.*

Water Resources of Tennessee. Warren R. King. Tenn. Dept. Education, Div. of Geology, Bull. 34: 1925. Principally a compilation of all existing discharge data for Tennessee streams, including parts of those streams in adjoining states. Records at two stations on Tennessee River go as far back as 1874 and 1889 respectively and one station on Cumberland River back to 1887. Gives precipitation records for 128 stations with good map of State showing isohyetal lines. This shows average annual rainfall of Tennessee fairly evenly distributed and ranging from 48 to 58 inches except in headwater region of Little Tennessee River in southwestern North Carolina where it increases to 84 inches over a small area. Report contains maps showing drainage basin boundaries, power generating plants, and transmission lines, and table giving data on public water supplies in Tennessee.—*David G. Thompson.*

NEW BOOKS

Researches in Concrete. W. K. Hatt. Lafayette, Ind.: Purdue University. Paper; 6 by 9 in.; pp. 102. Reviewed in Eng. News-Rec., 96: 290, February 18, 1926.—*R. E. Thompson.*

Practical Water-Power Engineering. Wm. T. Taylor. New York: D. Van Nostrand Co. Cloth; 6 by 10 in.; pp. 270; 32 line cuts, inserted charts, 33 tables. $10. Reviewed in Eng. News-Rec., 96: 292, February 18, 1926. —*R. E. Thompson.*

Depreciation in Public Utilities: Relation of Accrued Depreciation to Annual Depreciation and Maintenance. Delos F. Wilcox. New York: National Municipal League. Boards; 6 by 9 in.; pp. 112. $2. Reviewed in Eng. News-Rec., 96: 458, March 18, 1926.—*R. E. Thompson.*

Use of Water in Irrigation. Samuel Fortier. New York and London: McGraw-Hill Book Co. Inc., Cloth; 6 by 8 inches; pp. 420. $3. Reviewed in Eng. News-Rec., 96: 619, April 15, 1926.—*R. E. Thompson.*

Corrosion—Causes and Prevention. Frank N. Speller. McGraw-Hill Book Co., New York. This excellent book presents the most comprehensive treatment of the corrosion problem in so far as it relates to ferrous metals ever published. The author has been making a careful study of corrosion for a number of years, and fortunately has been so situated as to be in touch with more of the recent work on corrosion probably than any one else. The book is divided into two parts—Part I relating largely to the theory and cause and Part II to prevention.

It is only recently that the electrochemical theory of corrosion has gained general acceptance, and the most valuable contributions to the subject have been within the past 5 years. To review all the literature on corrosion and to make over 500 references in the text to such work is by no means a small task. The author has also contributed quite freely to the literature on corrosion and is well qualified to interpret the various views expressed by about 400 different authors. One reason why progress in combating corrosion has been slow is because there are so many conflicting opinions that it is difficult for the engineer to know which view to accept. It is believed that the present book will go a long way towards bringing order out of what has heretofore been almost chaos.

Chapter II presents in a clear and convincing manner the theories of corrosion, and shows why the electrochemical theory has gradually gained acceptance over the other theories such as, the acid, the colloidal, the direct chemical attack by oxygen, the peroxide, and others.

"Iron, like other elements, has a definite, inherent tendency to go into solution when placed in contact with water. Iron, however, can enter solution only by displacing some other element already in solution. For instance, a piece of iron placed in copper sulfate goes into solution, but at the same time copper is plated out and appears on the surface of the iron. In the ordinary case of iron immersed in water, hydrogen is the element plated out."

For corrosion to progress the hydrogen must be disposed of in some manner. The author believes that in most cases where the hydrogen-ion concentration of the solution is less than a pH of 5.5 (pH greater than 5.5) that the oxidation of nascent hydrogen to form water is the prevailing reaction. There is a slight liberation of hydrogen gas in many instances when the water is slightly alkaline, but the author states that this is not contrary to the electrochemical theory. He shows that there are a number of factors affecting corrosion rates, and that some of the secondary ones may exert a predominating influence and stop the primary reaction entirely. Chapter II probably is the outstanding one of the book and is well worth the careful study of any one interested in the theory of corrosion.

Considerable space is given to the influence of such factors as manufacture and composition of the metal. This is well worth the space given, for there are a great many structural engineers yet firmly of the opinion that the composition of the metal is the main factor influencing the rate of corrosion. The author shows quite conclusively that the amount of corrosion in ordinary commercial steel is governed much less by composition or metallurgical treatment than by the environments in which the metal is used. With the exception of ferrous alloys high in silicon, chromium, or nickel, the

composition of commercial iron and steel is shown to have little influence on the corrosion of metals exposed underwater or underground where only a limited amount of oxygen is available. The composition is a more important factor when exposed to the weather where there is alternate wetting and drying.

Chapter V, on the influence of factors external to the metal gives an excellent digest of the vast amount of research work which has been conducted on this phase of the problem. Corrosion is classified under 5 main headings—atmospheric, underwater, underground, chemical and electrolysis. Atmospheric corrosion is characterized by the presence of oxygen in excess, moisture being present only part of the time. In corrosion underwater the controlling factors are oxygen concentration, hydrogen-ion concentration, composition of the water, protective coatings, rate of motion, and temperature. Corrosion underground is similar to corrosion under water, but other factors may have considerable influence. Such corrosion is usually characterized by marked pitting.

The chapter on the methods of corrosion testing will prove of interest to any one conducting similar experiments. An attempt to work out some means of expressing the relative rate of corrosion has been made, and while the value of any such method may be open to question, the expression of corrosion rate in inches penetration per year as used by the author throughout the book is probably the best method that can be used.

Part II of the book on preventive measures should be of great interest to all users of iron products. The relative merits of the various kinds of paints and metallic coatings are discussed in considerable detail. The type of coating most suitable for a specific purpose will depend on the conditions of exposure. The composition of the various kinds of coatings and the best methods of applying brings together a vast amount of scattered information and will enable one to determine more accurately the kind of coating most suitable for a specific condition.

Water works officials are more interested in the prevention of corrosion underwater and underground than under other conditions. The author gives a very good digest of the literature on this phase of the problem. From the fact that preventive measures under water are just now receiving consideration, we should not expect a solution to all our problems in a book published at the present time. Several methods, such as the treatment with alkalies and sodium silicate are given.

A very good outline of chemical corrosion is given. This applies to unusual conditions such as corrosion in acids, alkalies and strong salt solutions; that is, conditions beyond the ranges of natural waters. The author concludes that the greatest need at present on chemical corrosion is more facts.

The prevention of corrosion underground is discussed in detail. Soil corrosion is more complex than atmospheric or water corrosion, and it is more difficult to make comparative tests. The description of several types of protective coatings which have proven successful in corrosive soils and the manner of applying the coating to the pipes is very interesting. Stray current electrolysis is briefly defined. The damage done a structure is where the current leaves it for the earth. The best means of avoiding electrolysis is given in a summary of good practice in street railway construction.

From the standpoint of the power plant operator, the book is of great value. Chapter X, dealing with Deaeration and Chapter XI, on the Treatment of Boiler Feed Water, are of special interest in this respect. The various types of deaerators now in practical operation in a number of stations are described and the results of deaeration in the inhibition of corrosion are clearly indicated. The subject matter in this chapter is timely, since the present tendencies toward higher steam temperatures and pressures in modern power plants demand feed water from which all oxygen has been removed.

The general question of feed water treatment has been reviewed by the author in a clear and concise manner. He has pointed out the necessity of proper feed water treatment as a factor in the prevention of corrosion of boilers and other power plant equipment.

The reviewers find very little to criticise. The author has covered the subject well, but he makes it plain that there is not as yet an answer to all corrosion problems and stresses the need for more research work. This book is a very valuable addition to our library, and no water works official should be without a copy.—*John R. Baylis and S. T. Powell.*